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The Modern Single-Phase Railway Motor.

III.

SOME OF ITS CHARACTERISTICS.

By ANDREW STEWART, A.M.I.E.E.

(*Continued from page* 291.)

THE general performance of these single-phase motors does not differ seriously from that of standard direct-current motors. On comparing Fig. 12, which shows the performance of a 550 h.p. direct-current motor, one of four, mounted on a New York Central Railway electric locomotive of 2,200 h.p., with Fig. 13, which shows the performance of a "Westinghouse" single-phase motor of less power, it will be seen that the characteristics of the two types are similar, *i.e.*, the contour of the curves is similar, showing that the machines possess almost identical characteristics.

The tractive effort for a given current is almost identical, whether for direct-current or single-phase, a given current producing a similar torque in each case.

Though the two motors are not identical in horse-power the same current should produce nearly the same torque, and this is just what takes place, as a comparison of the two torque curves will show: indeed, the single-phase railway motor can be built to do all that a direct-current motor will do.

There are, however, two features where the two types of motors do differ, viz., in point of efficiency and weight per horse-power.

The curves Figs. 12 and 13 do not bring out the relative merits of the two types on the first point very clearly, for the former is that of a slow speed gearless motor of a type that has had the benefit of many years' experience, and so represents the product of a considerable accumulation of talent and experience. The single-phase machine

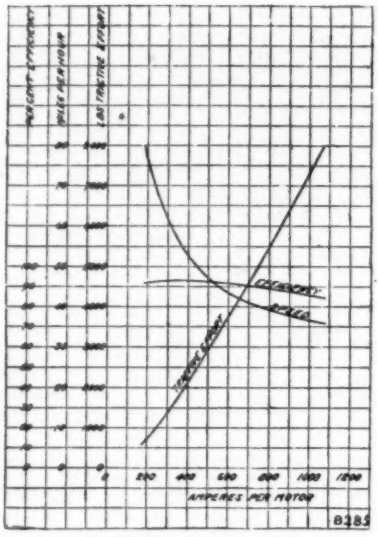


FIG. 12.—PERFORMANCE OF 550 H.P. DIRECT CURRENT MOTOR.

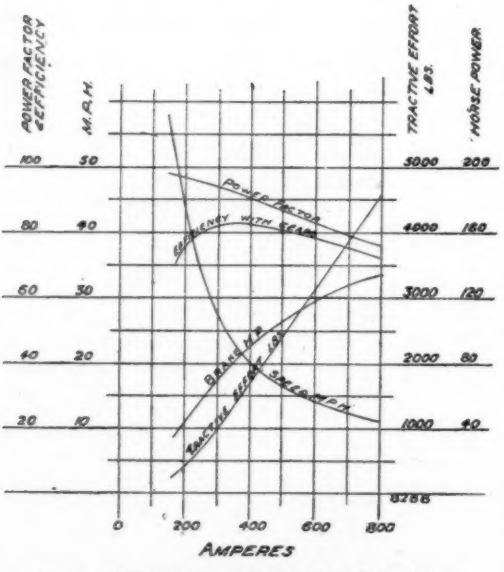


FIG. 13.—PERFORMANCE CURVES OF SINGLE-PHASE RAILWAY MOTOR, 225 VOLTS, 25 PERIODS.

(Fig. 13) represents a smaller motor, as there are at the time of writing no data available of large single-phase motors comparable with the large direct-current motor, the curves of which are shown. This smaller machine is therefore naturally a less efficient piece of apparatus; nevertheless, when comparing smaller direct-current motors with corresponding single-phase machines, there is a difference in efficiency which tells against the single-phase motor. One prominent cause of loss of efficiency in the single-phase motor is the fact that the field or stator is subjected to a variable magnetic field, hence there are losses in this part which do not exist in the corresponding direct-current motor. Moreover, owing to the less perfect utilisation of the active material in a single-phase motor there must be more of it for a given output; and any increase in the amount of active iron in an alternating-current motor means an increase in the hysteresis and eddy-current losses.

If one takes standard single-phase traction motors as made by such representative firms as the Westinghouse Co., General Electric Co., and Allgemeine Elektricitats Gesellschaft, one finds a difference of from 7 to 10 per cent. in efficiency; in some cases a still greater difference is apparent. The Westinghouse Co. show a maximum efficiency of 86 per cent. for their 225 h.p. series single-phase motor, and published data regarding direct-current machines of the same output show efficiencies of the order of 92 per cent. The 550 h.p. direct-current motor (Fig. 12) shows 93 per cent. efficiency.

With regard to weight the direct-current machine, whose curves are shown (Fig. 12) weighs with controlling gear 25 lbs. per h.p.; this is, however, exceptional. Most electric railway equipments will be found to weigh, motors and controlling

gear, about 55 to 80 lbs. per h.p., while as far as can be calculated from the published data on the railways now equipped with single-phase electric motors, and from the data supplied by manufacturers, the single-phase system involves a weight of 88 to 105 lbs. per h.p.

It may be remarked here that the three-phase electric locomotives used to handle the trains through the Simplon Tunnel, which have a capacity of 1,000 h.p. in two motors of 500 h.p. each, have an electrical equipment weighing 63 lbs. per h.p., and the motors have an efficiency of 92 per cent., all of which goes to indicate that the single-phase system has a long way to go before it can seriously threaten the direct-current, or the polyphase system, on these two important points.

Of course both the older systems profit by an accumulation of experience which the younger system does not possess, and it may be calculated to show some improvement after the lapse of a moderate period. It has, however, inherited the combined experience of designers who have been working on direct and alternating current machinery for many years, so that the principles governing the designs are well known, hence nothing like the progress that has characterised direct-current and polyphase designs may be looked for; indeed, it seems that on these two points the single-phase motor is handicapped with disadvantages that are inherent to it.

One must not suppose, however, that they are any effectual barrier to its progress; in the first place a single-phase motor will do all that a direct-current motor will do, and display the same characteristics, if we leave weight and efficiency out of consideration. Now, the extra weight is, after all, not so serious as one might suppose. It is true that it may involve stronger underframes, and punish the permanent way at junctions, but against this may be put the fact that it increases the weight available for adhesion, and many railway engineers allege that this is one point in which the electric locomotive is most likely to prove deficient.

The question of efficiency comes within a different category, for the acknowledged deficiency of the single-phase motor in this respect is almost balanced by the fact that the rotary converter losses in a direct-current system are eliminated, so that, as the showman once put it, what is lost on the swings is made up on the roundabouts! The total losses, power station to car wheels, need not necessarily differ much in either system, and the single-phase system has the advantage in simplicity of equipment both outside and inside the train. Labour charges at the sub-stations would be much less than for a direct-current system, as the sub-stations would not contain moving machinery requiring more or less skilled attention.

I think I have shown that, notwithstanding the admitted shortcomings of the single-phase motor, it possesses many features which commend themselves to engineers, and while those who take the view that it is a passing fancy, one phase only in the evolution of a satisfactory electric railway system, have no difficulty in finding arguments on one side or another, it must be concluded that the single-phase railway motor presents not a few features which justify one in concluding that it will play a most important part in electric railway development.

Testing a Centrifugal Fan.

III.

By C. L. BROWNE.

(*Continued from page* 296.)

TRACING the path of a particle of air on its way through a single inlet centrifugal fan, it first enters the eye of the fan with a velocity u_0. Now if the width of the fan wheel is greater than one-quarter of the diameter of the fan inlet, there will be a loss of head due to the sudden enlargement of the radial passage into the wheel, and the large majority of fans on the market are considerably wider than one-quarter of the diameter of the fan inlet, owing to the fact that the output per revolution may be increased to a certain extent by widening the fan above the limit referred to, and that by a slight additional cost in its manufacture.

After entering the fan, the particle of air has its motion changed from an axial to a radial direction, and in the most efficient fans this change of direction is brought about gradually, and with little shock, by a suitably coned wheel centre.

The air is then picked up by the fan blades.

Referring to Fig. 7, assume the line *X Y* to be the path of the particle of air passing through the fan wheel with reference to the latter, the wheel rotating in the direction shown by the arrow.

Let C_2 be the velocity of rotation in feet per second of the inner edges of the blades, and C_1 that of the outer tips.

Now the particle of air entering the wheel in a radial direction, with a velocity u_2, is picked up by the inner edges of the blade and its direction suddenly changed from u_2 to u. Call the angle made by the line v_2 with the tangent to the circle representing the path of the inner edges of the blades θ.

Now when a sudden change in velocity and direction takes place such as that shown in Fig. 8 from *J K* to *J M*, where *J K* represents a velocity u_2, and *J M* a velocity u, it can easily be proved that the loss of head incurred $= \frac{K M^2}{2g}$, and this loss is obviously least when *K M* is perpendicular to *J M*.

Therefore it would appear that in order to avoid any unnecessary loss of head at entry to the space between the fan blades, the direction of mean flow should be such that $\cot \theta = \frac{c_2}{u_2}$.

This efficiency of the fan alone, which will be designated by the letter η, is analogous to the hydraulic efficiency of a centrifugal pump.

It is usual, however, to include in the power absorbed by the fan that due to the friction in the fan shaft bearings, and the mechanical efficiency, including this additional work, will be expressed by the letters η_m, and this is the mechanical efficiency given in the appended tests.

The manometric, or pressure, efficiency of a centrifugal fan is expressed in terms of the total pressure head maintained in feet of air, and the corresponding tip speed of the blades in feet per second, and the formula for this efficiency is $\frac{gH}{C_1^2}$, where H = total head in feet of air against which the fan is working, and C_1 the tip speed of the blades in ft. per second, g being 32·2.

It might at first be assumed that the manometric efficiency of a fan working at zero orifice would always be ·5, since the air within the fan wheel would appear to be rotating at the same angular velocity, hence C_1 would $= \sqrt{2gH}$ and $\frac{gH}{2gH} = ·5$. In practice, however, it is found that when the outlet from the fan housing is completely closed, the air still circulates through the wheel, being discharged again through the inlet opening of the fan; thus it will be seen, on referring to test sheet No. 2, that the manometric efficiency of this particular fan at zero orifice is ·752.

There is still another ratio used by fan manufacturers, and that is the volumetric efficiency, the formula being used to compare the volume discharged with the tip speed of the fan wheel and the dimensions of the fan.

The formula most commonly used for this purpose is $\frac{Q}{C_1 r_1^2}$, in which Q = the cubic feet of air discharged per second, C_1 the tip speed of the wheel in feet per second as before, and r_1 the outer radius of the wheel in feet.

This formula would be correct for centrifugal fans provided that the ratio of the width of the wheel to its diameter were the same in all fans, but this is very far from being the case.

A narrow fan of large diameter may have a higher volumetric efficiency than one of less diameter and greater width, and yet may be designed to give the same value for $\frac{Q}{C_1 r_1^2}$.

For this reason the writer has, in the test sheets appended, made use of another formula for volumetric efficiency, the expression used being $\frac{Q}{C_1 D. W}$.

Q and C_1 being as before the volume discharged and the tip speed respectively, D the diameter of the fan, and W its width, both dimensions being in feet.

It will be seen that the volumetric efficiency varies directly as the cubic feet discharged per second and inversely as the tip speed, and becomes unity when the volume discharged in cubic feet per second becomes such as to necessitate a velocity equivalent to the tip speed of the fan wheel in order to pass it through an effective area equal to the rectangle $D. W$ containing the fan wheel.

American manufacturers have another method of stating the capacity of a fan, and make use of the following formula

$$\text{capacity area} = \frac{D. W}{X}$$

where D = the diameter of the wheel, and W its width at circumference, both dimensions being in inches, X is a constant depending upon the type of fan and casing.

The expression $\frac{D. W}{X}$ is used to denote what in America is known as the square inches of blast, that is to say, the effective area in square inches over which the fan will maintain the pressure theoretically due to a velocity corresponding to the tip speed of the blades.

For further particulars of American fans, the interested reader is referred to a handbook on the subject by Prof. Kenealy, of America, but in many cases both the mechanical efficiencies and the capacities given are greatly exaggerated.

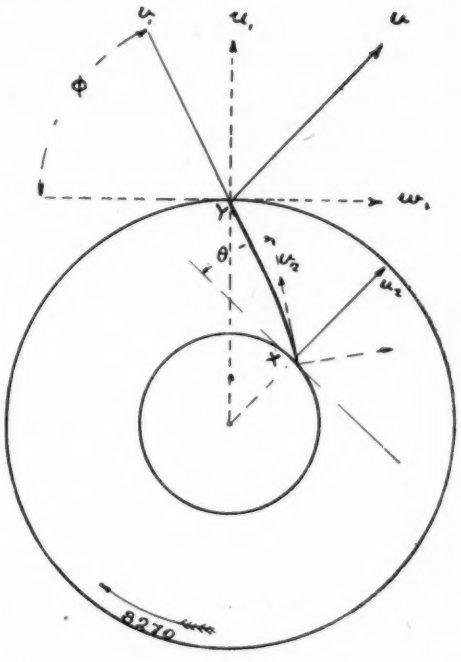


FIG. 7.

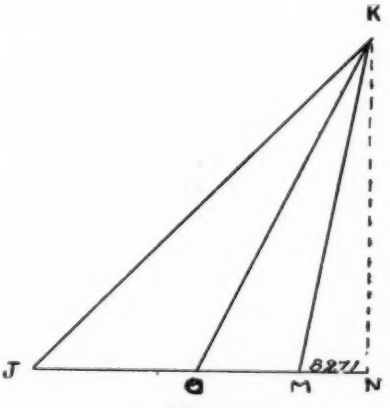


FIG. 8.

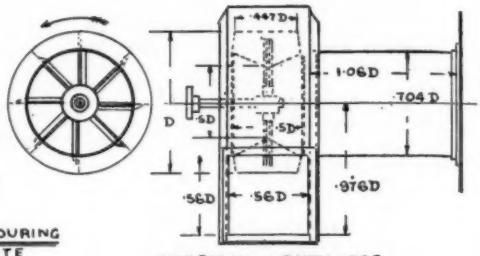
The tests Nos. 1 and 2 have been selected from a number of others, not for the reason of any special excellence in their design, but because of the marked dissimilarity in their

TEST SHEET No 1

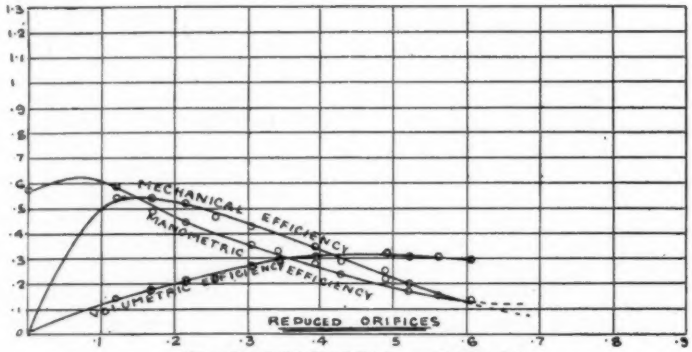
• ASSUMED COEFFICIENT OF INFLUX $\gamma = .83$. ALL OTHER COEFFIENTS OF INFLUX AND EFFLUX ARE ASSUMED TO BE UNITY.

o MECHANICAL EFFICIENCIES η— INCLUDE FRICTION OF ONE FAN SHAFT BEARING.

NOTE: TIP SPEED OF WHEEL DURING TEST 5000 FEET PER MINUTE



AMERICAN VENTILATOR



CHARACTERISTIC CURVES

$\frac{C_c}{\sqrt{2gH}}$	• $\frac{u_2}{\sqrt{2gH}}$	$\frac{u}{\sqrt{2gH}}$	$\frac{V_a}{\sqrt{2gH}}$	o η—	$\frac{gH}{C^2}$	$\frac{Q}{C_cDW}$	$\frac{Q}{DW\sqrt{2gH}}$
·929	0	0	0	0	·575	0	0
·972	·185	·0472	·197	·538	·582	·1328	·129
1·014	·245	·0628	·261	·536	·488	·1700	·172
1·065	·306	·0784	·326	·515	·440	·2028	·216
1·119	·3675	·0940	391	·472	·400	·2175	·259
1·180	·429	·1097	·456	·430	·354	·257	·303
1·236	·481	·1250	·522	·407	·327	·2805	·346
1·324	·550	·1401	·585	·345	·279	·297	·393
1·416	·612	·1558	·650	·289	·234	·300	·431
1·536	·698	·1778	·742	·253	·215	·317	·487
1·703	·748	·1874	·784	·195	·173	·305	·520
1·849	·800	·2040	·850	·154	·147	·304	·560
2·030	·860	·2190	·914	·121	·122	·298	·605

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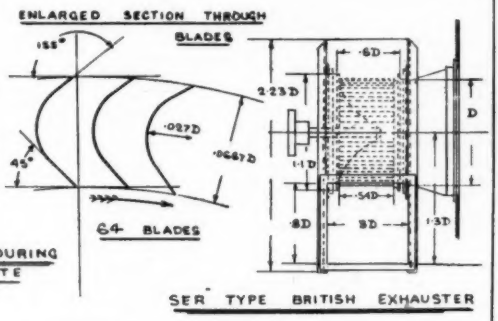
TEST SHEET Nº 2

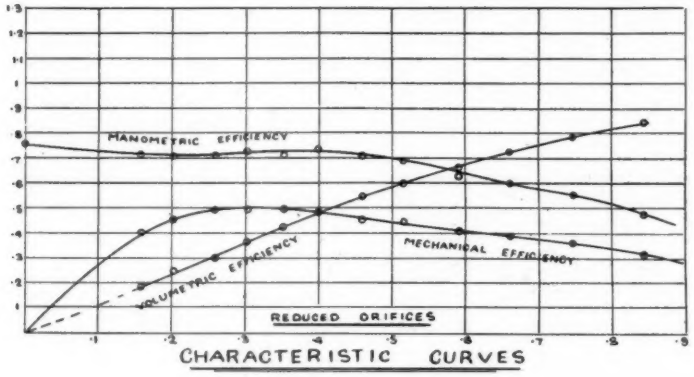
o ASSUMED COEFFICIENT OF INFLUX = γ = ·83. ALL OTHER COEFFIENTS OF INFLUX AND EFFLUX ARE ASSUMED TO BE UNITY.

• MECHANICAL EFFICIENCIES η_m INCLUDE FRICTION OF ONE FAN SHAFT BEARING

NOTE: TIP SPEED OF WHEEL DURING TEST = 8000 FEET PER MINUTE



SER TYPE BRITISH EXHAUSTER



CHARACTERISTIC CURVES

$\frac{C_1}{\sqrt{2gH}}$	$\frac{u_2}{\sqrt{2gH}}$	$\frac{u_1}{\sqrt{2gH}}$	$\frac{V_a}{\sqrt{2gH}}$	η_m	$\frac{gH}{C^2}$	$\frac{Q}{C_1DW}$	$\frac{Q}{DW\sqrt{2gH}}$
·816	0	0	0	0	·752	0	0
·837	·1843	·0717	·1748	·398	·717	·180	·151
·840	246	·0950	·2415	·457	·705	·239	·202
·844	·3130	·1214	·3073	·483	·704	·299	·260
·838	·3659	·1427	·3590	·480	·721	·360	·302
·837	·4310	·1670	·4235	·490	·717	·420	·352
·834	·492	·1910	·4830	·470	·725	·480	·400
·862	·530	·2050	·5205	·451	·703	·539	·461
·860	·616	·2380	·6050	·445	·684	·599	·515
·897	·678	·2620	·6650	·402	·621	·660	·592
·916	·740	·286	·7260	·381	·592	·720	·660
·960	·795	·3075	·7800	·351	·547	·778	·748
1·011	·864	·3340	·8480	·310	·476	·835	·845

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construction. They will be referred to in future as fans Nos. 1 and No. 2 respectively.

Referring to these sheets it will be seen that no actual velocities are given, but the ratio between the actual velocity under consideration and that corresponding to the pressure set up by the fan. The water gauge corresponding to these velocities can be ascertained for any value obtaining in ordinary practice on referring to the table given in the first article.*

The notation adopted in the test sheets is the same as has been used throughout this article.

Column 1 gives the ratio between the tip speed of the fan wheel and the velocity corresponding to the pressure set up.

In columns 2, 3, and 4 similar ratios are given for the velocities at inlet, radial discharge from the fan wheel, and discharge from the fan housing respectively.

η_m, $\frac{gH}{C_1^2}$, $\frac{Q}{C_1 D. W}$ are the mechanical, manometric and volumetric efficiencies respectively.

The last column gives the various "reduced orifices" at which the fan is working.

The term "reduced orifice" is used to connect the orifice at which the fan is working with the dimensions of the fan.

The expression used for "orifice" by Bryan Donkin and others is $\frac{Q}{\sqrt{gH}}$, and not only is the value $\sqrt{2\,gH}$ more convenient to use than $\sqrt{gH}$, but the value of the expression $\frac{Q}{\sqrt{gH}}$ will change for different sizes of the same type of fan, and the object in arranging these test sheets was to make the values therein contained applicable as far as possible to all sizes of fans of similar proportions. An expression for reduced orifice that has been considerably used on the Continent is $\frac{Q}{r_1^2\ \sqrt{gH}}$, and against the use of this term can be urged the same objections as in the case of the ratio considered with reference to the volumetric efficiency, and in which $D.\ W$ was substituted for r_1^2 for the reasons then given. It should be noted, however, that the ratio between the reduced orifice and the corresponding volumetric efficiency will be unaltered by the substitution of $D.\ W$ for r_1^2, this ratio being in either case $\frac{C_1}{\sqrt{2gH}}$ as given in the first column in the test sheets.

Above these columns are set out the characteristic curves of the particular fans tested, with the efficiencies as ordinates and reduced orifices as abscissæ.

Fan No. 1 is of a type widely u ed in this country; the radial blades are simple and cheap to manufacture.

Fan No. 2 is of the "Ser" type, and the blades are short radially after the manner of the "Ser" and "Mortier" fans, the shortening of the blades giving a large inlet into the fan wheel.

It was pointed out above that the air on entering the wheel of a fan could be picked up without serious loss of head by blades moving at a high speed, provided that the blades at intake be curved forward in the direction of rotation in accordance with the formula given.

This means that the inlet of the fan may be enlarged by decreasing the radial length of the blades. It was also shown that the manometric efficiency of a fan could be improved by increasing the value of ϕ. The angle ϕ is, as previously indicated, increased by curving the blades forward at tip, in the direction of rotation, and the greater the number of blades employed the more nearly can φ, the mean angle of flow, be made to coincide with the forward curvature of the blades.

It will also be evident that the greater the number of curved blades employed the greater must be the inner diameter of the wheel, in order to prevent the restriction of the radial flow of the air into the wheel.

When the blades are curved forward, up to a certain point the greater the number of blades employed the greater will be the water gauge set up for a given tip speed, but a point will be reached when the friction between the air and the blades will cause a serious drop in the mechanical efficiency of the fan.

Provided that the air can be picked up without shock, the advantage of a large unrestricted inlet to the fan is obvious, the velocity of the entering air being low and the loss of head on entry equally so. The disadvantage accompanying a high value of ϕ is the increased loss of head of the air on entering the volute.

As with other fans, the increased width of the wheel is not followed by an equal increase in the volume of air discharged.

The result of the proportions adopted is that high manometric and volumetric efficiencies have been obtained for a small weight of fan, at the sacrifice of some of the mechanical efficiency otherwise obtainable with fans of this type.

(To be concluded.)

* Pages 218, 219.

Foundry Blower Practice.

By W. B. SNOW.

MODERN foundry practice in the melting of metals is fundamentally dependent upon the blower. As the successor of the blow-pipe and the bellows, it has made possible the massing of fuel in large quantities, with greater imposed resistance, the production of higher temperatures, and the better utilisation of the heat in the furnace.

The primary function of a blower is to move air against resistance. Its performance is dependent upon the relation expressed by the formula:

$$V = \sqrt{2gh} \qquad [1]$$

in which V = velocity in feet per second
h = head in feet
g = acceleration due to gravity = 32·16

or $$V = \sqrt{2g\frac{p}{d}} \qquad [2]$$

when h is expressed in terms of p = pressure and d = density.

When applied under the conditions of
p = pressure in ounces per square inch
d = density or weight per cubic foot of dry air at 50° F. and under atmospheric pressure of 14·69 lbs. or ·235 oz. = 0·077884 lbs., formula [2] becomes

$$V = \sqrt{64{\cdot}32 \times \frac{p \times 144}{16 \times 0{\cdot}077884 \times \frac{235+p}{235}}} \qquad [3]$$

which reduces to

$$V = \sqrt{\frac{1746659 \times p}{235+p}} \qquad [4]$$

Allowance is evidently made therein for compression of air, but not for change of temperature during discharge.

The velocities in the basis Table I. were calculated by this formula. The tabulated volume is in each case the product of velocity and effective area.

The theoretical horse-power is the product of pressure, velocity and effective area. For refined work, or under conditions of wide variation from the basis of the table, corrections should be made for differences in humidity and temperature.

In the ordinary processes of the foundry, where iron or the less refractory metals are to be reduced, the resistance of the crucible, air, or cupola furnace will roughly range from somewhat above 1 oz. to a possible but usually unnecessary pressure in excess of 20 oz. per sq. in.

Up to about 8 oz. the fan blower cannot be excelled for convenience and efficiency. From 8 to 16 oz. the field is fairly divided between the fan and the rotary types, the advantage gradually shifting from the former to the latter as the pressure increases. Above 16 oz. the superiority of the rotary type is manifest, until it in turn encroaches upon the efficient field of the blowing engine at about 5 lbs.: a pressure far in excess of the practical requirements of the foundry. The air compressor, as an aid to combustion, is economically useful only in connection with the burning of liquid fuel.

The fundamental differences between the fan and the rotary type of blower lie in the manner of creating pressure and in the effect of resistance.

In the fan type, velocity is given to the air in its passage from the inlet to the circumference of the revolving wheel. This is transformable into pressure with corresponding density within the enclosing case and connections; the pressure being dependent upon the number of revolutions. In the case of a fan blower at constant speed, the volume and power decrease as the resistance increases. When the outlet is closed the wheel continues to revolve at the same speed, but without effective delivery, and with minimum power expenditure.

In the rotary, or so-called "positive" type, air in regularly succeeding volumes is imprisoned by one or more enclosed revolving impellers, and forced forward against the imposed resistance. It is thereby compressed to a density, and given a pressure proportionate to that resistance. This pressure is fundamentally independent of the number of revolutions. The delivery remains practically constant for a given speed as long as discharge is permitted, while the power expenditure increases with the resistance. When the outlet is closed the power required is at the maximum, and the displacement, though ineffective, is just

TABLE I.

RELATIONS OF PRESSURE, VELOCITY, VOLUME AND HORSE-POWER.

Pressure per sq. in. Ozs.	Velocity of Dry Air at 50° F. escaping into outer system through any shaped orifice.		Volume discharged in One Minute through an Orifice having Effective Area of one sq. in. Cub. ft.	Horse-Power required to move given Volume under given Conditions.
	Feet per sec.	Feet per sec.		
1	86·03	5 161·7	35·85	0·00978
2	121·41	7 284·4	50·59	0·02759
3	148·38	8 902·8	61·83	0·05058
4	170·98	10 258·6	71·24	0·07771
5	190·76	11 445·5	79·48	0·1084
6	208·53	12 511·9	86·89	0·1422
7	224·77	13 486·4	93·66	0·1788
8	239·80	14 387·9	99·92	0·2180
9	253·83	15 229·6	105·76	0·2596
10	267·00	16 020·4	111·25	0·3034
11	279·70	16 768·1	116·45	0·3493
12	291·30	17 478·2	121·38	0·3972
13	302·39	18 155·2	126·06	0·4470
14	313·38	18 802·7	130·57	0·4986
15	323·73	19 423·6	134·89	0·5518
16	333·68	20 020·7	139·03	0·6067
17	343·26	20 595·8	143·03	0·6631
18	352·52	21 151·0	146·88	0·7211
19	361·46	21 687·8	150·61	0·7804
20	370·13	22 207·5	154·22	0·8412

equal to the slip, up to the limit of power to drive and of strength to endure.

The construction and proportions of a prevalent type of cupola fan blower are illustrated in Fig. 1. The casing and wheel are provided with two inlets, which, in ordinary construction, are about one-half the diameter of the wheel. The width of such a wheel at its periphery ranges from 5 to 8 per cent. of the diameter, the width between side plates at the inlet being approximately one-sixth of the diameter. From six to eight major blades extend from inlet to circumference; between these are one, two or three times as many minor blades of about one-half the radial length. All blades are slightly curved backwards at the circumference of the wheel. The cast iron casing is of involute form, its greatest diameter being approximately 1¾ times the diameter of the enclosed wheel.

In the volume type, designed for much lower pressures, such as are required in air furnace operation, the peripheral width of the wheel ranges from 20 to 40 per cent. of its diameter. The casing is often of steel plate.

Refined consideration of blower design is not necessary in a discussion of foundry blower practice, but a knowledge of fundamental principles and empirical relations is essential to a clear understanding of the subject.

The manufacturers' rating of the type of blower shown in Fig. 1 is based upon the greatest effective area over which it will maintain the maximum velocity of discharge. As originally established by Sturtevant, this "capacity area" or "square inches of blast" is represented by the empirical formula

$$\text{Capacity area} = \frac{D\,W}{3} \qquad [5]$$

in which D = diameter of wheel in inches
W = width of wheel at circumference in inches.

This formula was derived from the pressure type of fan blower. The value of the divisor must necessarily vary with the proportions of the wheel, the number of inlets, the number and curvature of the blades, and the form of the enclosing case. But as a merely arbitrary basis, the formula has been generally accepted for the ready comparison of wheels of substantially the same type. Manifestly the maximum velocity of discharge will create the maximum total pressure. As a factor in the manufacturers' rating this attainable velocity has been accepted as being equal to the circumferential speed of the wheel. This assumption is by no means universally correct.

Recent developments in fan construction with very large inlets, numerous shallow blades, and unusual width, show discharge velocities far in excess of the circumferential speed, approximating a theoretical maximum

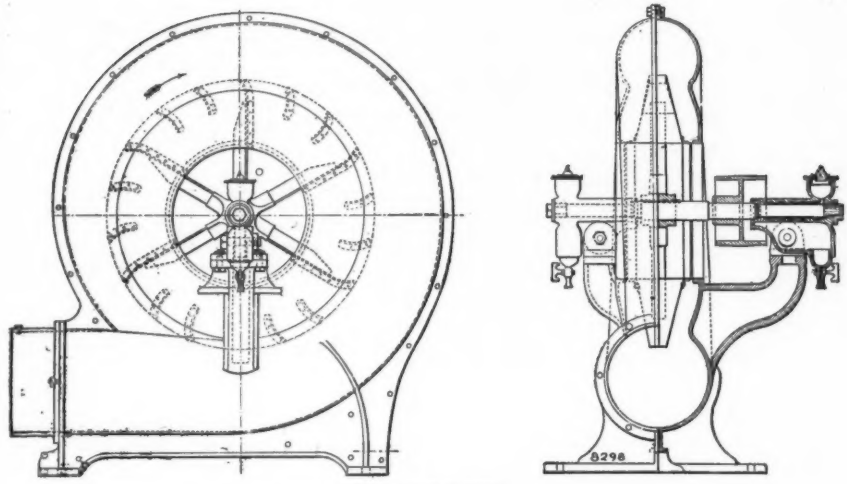

FIG. 1.—FAN BLOWER.

of twice that speed. But successful application of such fans has not yet been made under the resistance obtained in cupola practice.

It is evident that, disregarding the effect of changes in density and temperature, the following relations should hold for a given fan with constant capacity area:—

(*a*) The volume varies directly as the revolution; (*b*) the pressure varies directly as the square of the revolutions; (*c*) the power varies directly as the cube of the revolutions.

These relations clearly point to the economic desirability of closely proportioning the fan to the work it is to perform. An increase of only 25 per cent. in the speed, which may be necessitated by deficiency in the volumetric capacity of a given fan, nearly doubles the power required, and creates a pressure more than 50 per cent. in excess of that at normal speed. It is seldom that the sum of fixed charges and operating expense cannot be materially reduced by substituting a larger and more costly fan for one that must be run at unnecessary speed to deliver the required volume.

The speed of a fan is usually fixed, and variations occur only in the effective area of discharge. In cupola practice such variation is extensive, and changes often succeed each other with frequency. Hence it is difficult to proportion the fan to secure the most economical average performance.

It must have capacity to deliver the required volume under the greatest resistance toward the end of the heat, but the power provided must be sufficient to drive it during the early part of the heat, when there is less resistance, greater delivery, and consequently more work to be done.

For the ordinary type of fan it has been generally accepted that within the capacity area—

(*a*) The velocity and pressure are maximum and constant; (*b*) the volume and horse-power are proportional to the area.

These relations are only approximate, as is evident from Fig. 2. The curves are characteristic of an individual instance in which the fan ran at constant speed while discharging through various outlet areas. All values are relative to the performance at capacity area. Changes in the proportion of the speed of the fan would materially affect these relations, causing them to approach or recede from the conditions expressed in the preceding paragraph, and shifting the point of maximum efficiency.

These curves serve to show that—

(*a*) Maximum efficiency in power and pressure are secured at or near the capacity area; (*b*) the power per unit of volume and the pressure decrease as the discharge area and volume increase; (*c*) with closed outlet the power is approximately one-third of that at capacity area.

From the preceding it must be manifest that no simple, exact basis of calculation

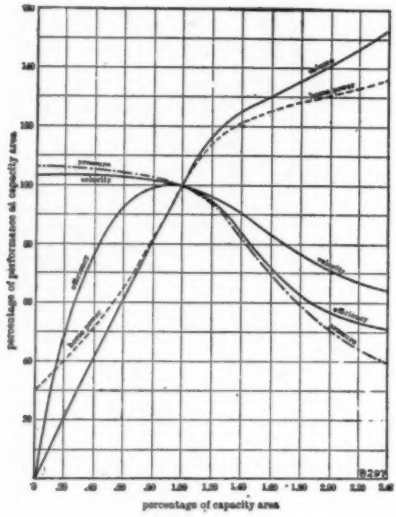

FIG. 2.—RELATIVE PERFORMANCE OF A FAN AT CONSTANT SPEED WITH VARIABLE OUTLET AREA.

can be established for varying fan proportions and conditions. For all practical purposes, however, the manufacturers' basis, although only approximately correct, is sufficiently accurate, particularly in cupola practice, where operation at or near the capacity area is essential.

Upon this basis Table 2 has been calculated to show the performance at capacity area per inch of peripheral width of typical diameters of cupola fan blowers. Basic values are taken from Table 1, the air being dry, and of 50° F. temperature; the velocity of discharge is taken as equal to the circumferential speed of the wheel, and the power as double the theoretical. While 50 per cent. efficiency is below that which may be attained in good cupola installations, it is always desirable to provide ample surplus above the power required at capacity area. Even a change of 50° from the ordinary inlet temperature makes a difference of about 10 per cent. in the power.

Characteristic types of single and double impeller rotary blowers are presented in Figs. 3 and 4. Numerous other designs are, or have been, in use.

In the type shown in the skeleton cross-section in Fig. 2, the single impeller is made up of three diamond-shaped blades extending from a central web. On either side of the web a stationary core fills the space within the inter-circumference of the blades,

TABLE II.

PERFORMANCE OF CUPOLA FAN-BLOWERS AT CAPACITY AREA PER INCH OF PERIPHERAL WIDTH.

DIAM. OF WHEEL INCHES CAP. AREA SQ. INS.	ITEM	TOTAL PRESSURE IN OUNCES PER SQUARE INCH										
		6	7	8	9	10	11	12	13	14	15	16
18 in. 6 sq. in.	r.p.m.	2660.0	2860.0	3050.0	3230.0	3400.0	3560.0	3710.0	3850.0	3990.0	4120.0	4250.0
	cu. ft.	520.0	560.0	600.0	640.0	670 0	700.0	730.0	760.0	780 0	810 0	830.0
	h.p.	1.7	2.1	2.6	3.1	3.6	4.2	4.8	5.4	6.0	6.6	7.3
24 in. 8 sq. in.	r.p.m.	2000.0	2150.0	2290.0	2420.0	2550.0	2670.0	2780 0	2890.0	2990.0	3090.0	3190.0
	cu. ft.	700.0	750.0	800.0	850.0	890.0	930.0	970.0	1010.0	1040.0	1080.0	1110.0
	h.p.	2.3	2.9	3.5	4.2	4.9	5.6	6.4	7 1	8.0	8.8	9.7
30 in. 10 sq. in.	r.p.m.	1590.0	1720.0	1830.0	1940.0	2040.0	2140.0	2230.0	2310.0	2390.0	2470.0	2550.0
	cu. ft.	870.0	940.0	1000.0	1060.0	1110.0	1160.0	1210.0	1260.0	1310.0	1350.0	1390.0
	h.p.	2.8	3.6	4.4	5.2	6.1	7.0	7.9	8.9	10.0	11.0	12.1
36 in. 12 sq. in.	r.p.m.	1330.0	1430.0	1530.0	1620.0	1700.0	1780.0	1850.0	1930.0	2000.0	2060.0	2120.0
	cu. ft.	1040.0	1120.0	1200.0	1270.0	1340.0	1400.0	1460.0	1510.0	1570.0	1620.0	1670.0
	h.p.	3.4	4.3	5.2	6.2	7.3	8.4	9.5	10.7	11.9	13.2	14.5
42 in. 14 sq. in	r.p.m.	1140.0	1230.0	1310.0	1380.0	1460.0	1530.0	1590.0	1650.0	1710.0	1770.0	1820.0
	cu. ft.	1220.0	1310.0	1400.0	1480.0	1560.0	1630.0	1700.0	1770.0	1830.0	1890.0	1950.0
	h.p.	3.9	5.0	6.1	7.3	8.5	9.8	11.1	12.5	13.9	15.4	17.0
48 in. 16 sq. in.	r.p.m.	1000.0	1070.0	1150.0	1210.0	1270.0	1330.0	1390.0	1450.0	1500.0	1550.0	1590.0
	cu. ft.	1390.0	1500.0	1600.0	1690.0	1780.0	1860.0	1940.0	2020.0	2090.0	2160.0	2230.2
	h.p.	4.5	5.7	7.0	8.3	9.7	11.2	12.7	14.3	15.9	17.7	21.0

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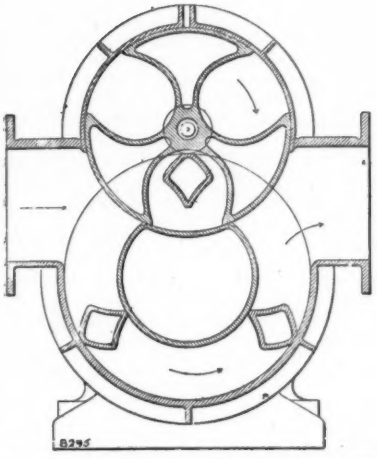


FIG. 3.—ROTARY BLOWER. SINGLE IMPELLER, TRIPLE BLADED TYPE.

forming, in connection with the enclosing case, an annular space within which they revolve. The rotor, which co-incidentally revolves in the smaller portion of the casing, successfully provides pockets to receive and pass the revolving impeller blades to the suction side of the blower, without allowing the escape of compressed air. The rotor is in effect an idler, which calls for no power expenditure other than that required to overcome friction.

In the type shown in Fig. 4, both impellers are symmetrical and counterparts of each other. The surfaces are so formed, and the impellers are so located on their respective shafts, as to permit of rotation with uniform clearance, and without metallic contact.

Release of air on the discharge side of each impeller is practically coincident with the cut-off of admission on the inlet side.

In both types the air passing through the inlet is imprisoned, and carried forward to the outlet side. Here it meets and mingles with an air of greater density, already compressed by previous action of the impellers. Equalisation of pressure instantly results. As a consequence there is more or less fluctuation coincident with the revolutions of the blower. The degree of fluctuation depends upon the ratio between the released volume and the total volume under compression, and also upon the extent to which the air has been previously compressed in transit through the blower. This occurs in the case of the single, but not of the double impeller type here illustrated.

The theoretical relations which prevail in the case of a rotary blower having a fixed free area of discharge and no slip, are identical with those already specified for the fan type operating within its capacity area, namely, the volume, and consequently the velocity, vary as the number of revolutions, the pressure varies as the square, and the power as the cube of the revolutions. But here the similarity ends, for in the fan the number of revolutions is an essential function of the pressure, while in the rotary blower they are entirely independent. In other words, material change of total pressure with the fan type can only be secured within the capacity area by change in revolutions, while with the rotary type great range in pressure is attainable, at constant revolutions, by merely varying the resistance.

Under conditions of constant speed, and variable outlet or resistance, the performance relations of a theoretically perfect rotary blower are as follows, the effect of changes in temperature and density being disregarded: (*a*) The volume is constant; (*b*) the velocity varies inversely as the effective outlet area; (*c*) the pressure varies inversely as the square of the outlet area, hence as the square of the velocity; (*d*) the power varies directly as the pressure.

But the mechanical necessity of clearance, and the consequent slip or backward leakage, affect these relations, particularly

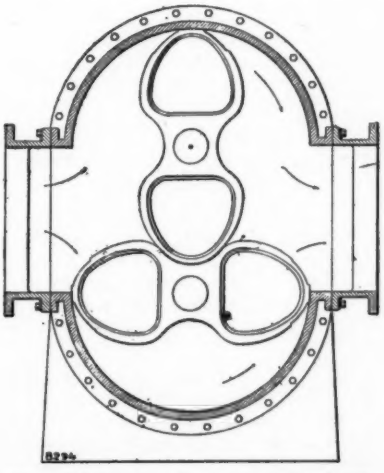


FIG. 4.—ROTARY BLOWER. DOUBLE IMPELLER TYPE.

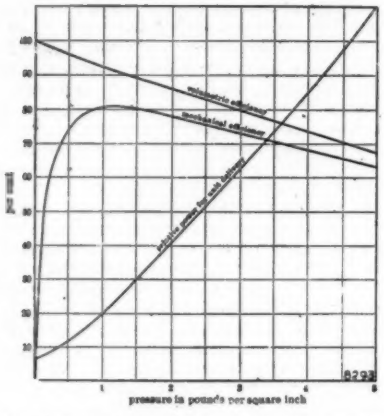


FIG. 5.—RELATIVE PERFORMANCE OF A SINGLE IMPELLER ROTARY BLOWER AT CONSTANT SPEED, WITH VARIABLE RESISTANCE.

as the conditions depart from the field of maximum efficiency. The slip is theoretically and, in practice, approximately proportional to the square root of the pressure difference between the atmosphere and the imprisoned air, that is, to the velocity which it creates. It therefore results that the velometric efficiency decreases as the pressure increases.

Fig. 5 presents characteristic curves showing relative performance of a single impeller blower of the type illustrated in Fig. 3. The rapid drop in mechanical efficiency at pressures below $\frac{1}{2}$ lb. is manifest.

The performance of a two-impeller type, like Fig. 4, at different speeds and resistances, is illustrated by the curves in Fig. 6. Volumes and horse-powers are relative.

Under specific conditions of constant speed and resistance, it might be possible to establish the superiority of one type of blower above the other, based primarily upon first cost and operative efficiency. But conditions vary as do blowers, which for commercial reasons are built in stated sizes from which selection must be made. Hence the problem is complicated, and the solution becomes to a considerable degree dependent upon the intangible factor of "adaptability."

With no purpose of definition as to advantages or disadvantages, the characteristics of the two types operating within practical limits may be thus summarised and contrasted:—

With a fan blower the maximum pressure is determined by the number of revolutions; with a rotary blower it depends upon existing resistance or the weighting of the relief valve.

The volume discharged by a fan blower is dependent upon the outlet area and the corresponding pressure; in the rotary type it is independent of both.

The maximum power is required when a fan blower discharges against the least, and when a rotary blower discharges against the greatest, resistance.

The fan blower automatically increases the created pressure as the opposing resistance becomes greater, until it equals the maximum pressure capacity of the fan. The volume, although coincidentally decreased, is rendered effective by the greater pressure, while the power is roughly proportional to the effective work. The rotary blower is likewise automatic up to the limit of pressure temporarily established by the resistance of the relief valve, but without material change of volume, and with increase in power. Above the pressure limit set by the valve, air escapes to the atmosphere, and the power expended thereon has no useful effect.

The weight and cost of a fan blower are far less, and the speed far higher, than in the case of a rotary blower; at low pressure the efficiency of the fan is superior, while at the higher pressures necessary in the cupola the rotary type excels.

As the total head or pressure created by a blower represents the sole means of producing movement of the air, whatever portion of this head is consumed in overcoming the frictional resistance of piping and fuel reduces by just so much the amount remaining available for the production of velocity. The greater the velocity the greater is the resistance.

Were the outlet in the casing of a fan blower to be made equivalent to the capacity area, the velocity and corresponding friction would be excessive. But in both the fan and rotary types, the area of the outlet is such that the velocity of discharge seldom exceeds 3,000 ft. per minute. Even this is so great that material saving in power may be secured in a long pipe by making its area considerably in excess of the blower outlet. For instance, the frictional loss in 100 ft. of 10 in. pipe with 3,000 ft. velocity will be practically 1 oz.; while that in a 12 in. pipe, passing about the same volume at 2,000 ft. velocity, will be approximately $\frac{3}{8}$ oz.

If a certain velocity pressure is required at the point of final delivery, it is manifest

that the blower, if in a distant location, must create a total pressure sufficiently in excess to allow for the loss by friction. A drop of a couple of ounces is not uncommon with an ordinary piping system.

The actual conditions in a conduit may be determined by a " Pitot " tube, and calculations of volume made therefrom. The most satisfactory form of instrument appears to be that devised by Mr. D. W. Taylor, and described in his paper before the Society of Naval Architects and Marine Engineers, November, 1905. Care must be exercised in the use of any form of pressure gauge in order to avoid misleading readings. This is particularly true regarding determination of pressure in the wind-box of a cupola, wherein the direction of air currents is uncertain.

The modern cupola furnace is typical of metallurgical progress in which conservation of heat has been secured by massing fuel and metal. As arranged in successive charges with a melting zone of maximum temperature beneath, the best possible opportunity is presented for the gradual ignition of the fuel and heating of the metal in their downward course.

It would at first appear that equal facility was provided for securing complete combustion, and that the quantity of air furnished might closely approximate the chemical requirements. But to secure the best results the volume is reduced in practice considerably below that theoretically required; of necessity incomplete combustion results. The conditions are closely similar to those in the blast furnace.

The reason for this condition is to be found in the arrangement of the superimposed charges of fuel and metal with relation to the air supply, which necessitates passing through the lower charges all of the air required for those above. Although perfect combustion with an excess of air is thereby secured in the melting zone, the tendency of excessive dilution is to cool the gaseous mixture to a temperature even below that of the molten iron. Under such conditions less heat is transferred to the upper charges, because of the higher velocity and lower temperature of the gases.

The air supply to a cupola is not, therefore, to be determined by the chemical requirements of the entire body of fuel, but by the excess which the lower charges are able to endure without disastrous cooling. The level of the ignition zone and the completeness of combustion are necessarily limited by this excess.

The introduction of two or more rows of tuyers with large aggregate area has served to distribute the air admission, to reduce the cooling effect in the melting zone, to raise the level of the ignition zone, and to perfect the combustion. But a coincident —and otherwise beneficent—increase in the height of the changing door has still prevented the attainment of complete combustion, although a larger proportion of the heat is utilised.

Authoritative chemical analyses of the escaping gases are exceedingly rare, but such as are available show that only about 50 per cent. of the carbon combines to form carbon dioxide. The balance escapes as an element of carbon monoxide having less than one-third of the heat value. In other words, only about two-thirds of the possible heat of combustion is utilised. This indicates a shortage of about 25 per cent. in the air supply.

The intermittent operation of the ordinary cupola is not conducive to the ready utilisation of the waste heat by external means, as is possible in the case of the blast furnace. Further economy is therefore to be sought within the cupola itself, and in the application of the blower thereto, presumably along the lines in which improvement has already been made.

The air supply to a cupola is usually expressed in cubic feet per net ton of iron melted. The amount necessarily varies

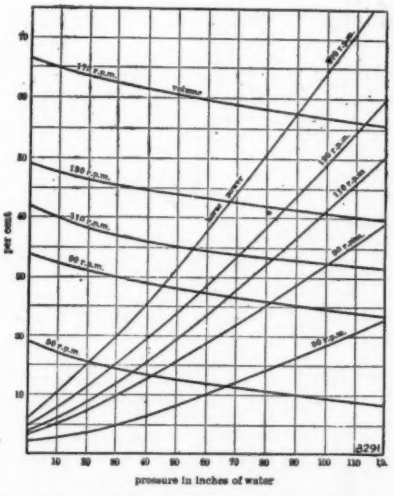


FIG. 6.—RELATIVE PERFORMANCE OF A DOUBLE IMPELLER ROTARY BLOWER AT VARIOUS SPEEDS AND PRESSURES.

with the melting ratio, the density of the charges, and the incidental leakage. Fair average practice is represented by the following:—

6 lbs.	iron	per	lb.	coke,	33,000	c. ft.	of air	per ton of iron
7	"	"	"		31,000	"	"	"
8	"	"	"		29,000	"	"	"
9	"	"	"		27,000	"	"	"
10	"	"	"		25,000	"	"	"

It is customary to provide blower capacity on a basis of 30,000 cubic feet, which corresponds to 75 or 80 per cent. of the chemical requirements with average coke, and a melting ratio of 7·5 to 1. This is evidently ample for any higher ratio.

Obviously, neither the rate of combustion nor the rate of melting can remain constant under the varying conditions within the cupola. In fact, it is not fundamentally necessary that they should. But the blower is usually run at constant speed, and delivers uniform volume except as reduced by resistance.

As a rule this reduction, which occurs only in the case of the fan, is relatively slight, for the volume (of which the velocity is a function) varies as the square root of the pressure. Hence, for instance, a 20 per cent. drop in pressure entails only about 10 per cent. loss in volume. Fairly constant pressure with a more regular, though not uniform volume, is therefore to be expected in fan blower cupola practice, as well as a moderate melting rate due to delayed combustion, resulting from reduction in air supply coincident with increase in resistance.

As ordinarily installed the resistance of a cupola will never exceed the pressure which a rotary blower can create if sufficient power is supplied. If no relief valve is provided, or it is set high enough to prevent escape, all air must be discharged through the cupola, hence the volume will be practically constant. As the pressure equals the resistance, considerable variation is to be expected during the heat, while, owing to the maintenance of uniform air supply, a more rapid rate of melting may be possible than with the fan.

These expectations are usually fulfilled in practice, although the contact lessens as the proportions of the blower to the cupola approaches the ideal. So far as the blower is concerned, its actual volumetric output, relatively to the cupola requirements, is the determining factor in the melting rate. Fundamentally the resistance regulates the volume in the case of the fan, while the volume regulates the resistance in the case of the rotary blower. Otherwise expressed, the fan type adjusts itself to its conditions, decreases the power and volume, and somewhat reduces the melting rate, while the rotary type in a resistless way continues to force through the cupola the prescribed volume, regardless of immediate requirements or power expenditure, and usually maintains the maximum hourly output.

For the purpose of illustration, extreme contrasts between the operation of a fan blower and a rotary blower are graphically presented in Fig. 7. These curves are based on tests reported by Mr. H. E. Field at the December, 1904, meeting of the Pittsburg Foundrymen's Association. The blowers, a No. 10 "Sturtevant" fan and a 33-cub. ft. "Connersville" rotary, were installed for alternate use in connection with a 54-in. lining cupola. So far as possible the charges were alike in weight and character in both cases. The scrap was heavy, and of such shape as to pack closely. These tests will be made the basis for some pertinent comparisons.

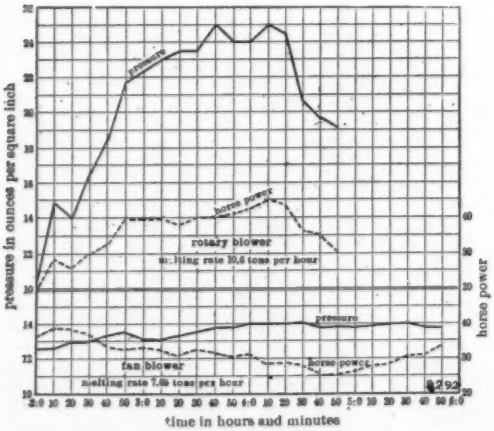


FIG. 7.—PERFORMANCE OF FAN AND ROTARY BLOWER ON A 54-IN. CUPOLA.

Here are practically identical conditions of cupola and contents, but great contrasts in operation which show the effect of variation in air volume and pressure. With the fan blower the pressure was comparatively constant, the variation being between 12½ and 14⅛ oz. in the wind-box, with an average of 13·6. The net power ranged from 25 to 38·5 h.p., with an average of 13·8. The pressure with the rotary

blower varied through the extreme range between 10½ and 25 oz., while the average stood at 20·63. The variation in horse-power was between 19 and 45, the average being 35·8.

With the fan 28·84 tons were melted in 3·77 hours, at the rate of 7·65 tons per hour, while with the rotary blower 2·82 hours were required to melt 31·5 tons, at an hourly rate of 10·6 tons, an increase of nearly 40 per cent. in output. This reduces to a net input of 4·09 h.p. per ton melted per hour with the fan, and 2·98 h.p. with the rotary blower—an apparent advantage of 27 per cent. in favour of the rotary.

By far the larger quantity of air was discharged by the rotary blower, the rate of melting being closely proportional to the volume, as may be shown by a careful analysis of the tests. The rate is low for the size of the cupola, extremely so in the case of the fan, and is in part at least the result of excessive resistance presented by large pieces of scrap.

The results shown by these tests emphasize the possible effect of changes in the relation of the blowers to the cupola. Had the rotary blower been of smaller capacity such excessive pressures would not have been necessary to force the constant volume through the cupola; the power would have been decreased, and the duration of the heat prolonged, with probable decrease in the horse-power hours per ton. Had the fan been run at higher, but not excessive, speed, to permit of passing a larger volume, which it was fully capable of delivering, the horse-power would have increased, the time decreased, and the power per ton per hour would certainly have more closely approached that required by the rotary blower.

A subsequent unofficial, but credible, test made upon the same cupola equipped with a No. 8 "Sturtevant" fan presents an instructive contrast. The conditions were identical with those in the previous tests, except that a small amount of very light scrap was charged. The results showed 9·41 tons melted per hour, with an average pressure of 12·5 oz. and a power expenditure per ton per hour less than 80 per cent. of that required with the No. 10 fan.

The preceding renders manifest the difficulties in the way of exactly proportioning blowers to the somewhat unknown conditions of their work, and likewise the futility of attempting to base comparisons of ultimate efficiency upon such limited experiments. In contrast thereto, it can be shown that a No. 10 "Sturtevant" fan, upon a 60-in. cupola, regularly melted 13·8 tons per hour, with an expenditure of 2·6 h.p. per ton, and a No. 8, upon a 42½-in., required only 2·9 h.p. per ton upon a total output of 6·46 tons per hour. And likewise that rotary blowers of identical size and quality have shown results both inferior and superior to those here reported.

The higher speed of melting, which, because of its ability to overcome excessive resistances, may be maintained by the rotary blower, is universally recognised, as is also the increased time thus rendered available for moulding before the first iron is tapped. But the greater pressure incident to the higher rate is much more severe in its cutting effect upon the lining, while the value of the time gained for moulding depends upon individual foundry conditions. The superior mechanical efficiency of the rotary type is, to a greater or less degree, offset by much lower first cost and fixed charges on the fan. The necessity of providing power capacity greatly in excess of the average in the case of the rotary blower is not to be overlooked. Neither is it to be forgotten that the brief duration of the heat reduces the difference in annual expenditure for power to a relatively unimportant item. For instance, under the exceptional conditions in the tests shown in Fig. 7, the daily difference in electrical horse-power hours input was only 20·3. On a basis of 10 hours per day this equals only 2 h.p. continuously exerted.

Theoretically, for otherwise constant conditions the following relations hold for cupolas and melting rates within the range of practical operation:—

(*a*) The melting rate with constant volume varies directly as the square of the diameter, that is, as the cross-sectional area of the cupola, and directly as the volume, as the square root of the pressure, and as the cube root of the power for a given cupola.

(*b*) The volume varies inversely as the square of the cupola diameter for a given melting rate, and directly as the melting rate for any cupola.

(*c*) The pressure with a given cupola varies directly as the square of the volume, that is, as the square of the melting rate, and as the depth of the charges for a given melting rate.

(*d*) The power with a given cupola varies directly as the cube of the melting rate, and as the cube of the square root of the pressure, and directly as the pressure for a given melting rate and any cupola, *i.e.*, inversely as the fourth power of the diameter for a given melting rate.

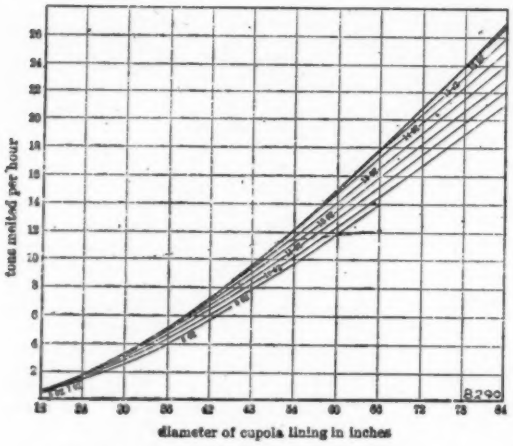


FIG. 8.—CUPOLA PERFORMANCE AT DIFFERENT PRESSURES.

(*e*) The power per ton per hour (the operating efficiency) for a given cupola varies directly as the square of the melting rate, that is, as the pressure; and for a given melting rate directly as the rate for a given pressure, directly as the pressure and inversely as the fourth power of the diameter.

(*f*) The duration of the heat for a total output for a given cupola varies inversely as the square root of the pressure.

These relations might well be the source of numerous formulæ for practical use were it possible to establish accurate coefficients. But the great variety in cupolas, tuyerage proportions, and character of fuel and iron, to say nothing of the difference in charging practice in different foundries, or even the variety in the same foundry, is bewildering and discouraging. Maximum efficiency in a given case can only be assured after direct experiment. But something short of the maximum is usually accepted in ignorance of the ultimate possibilities. But even though subject to some variation under working conditions, the preceding relations point clearly to the factors that make for maximum efficiency. It is obvious that pressure and melting rates should be as low, and cupola diameters as great, as practical considerations will allow.

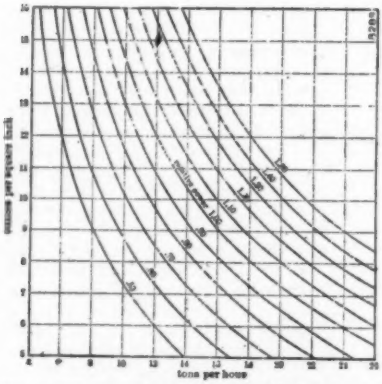


FIG. 9.—ROTATIVE POWER FOR DIFFERENT PRESSURES AND MELTING RATES.

High pressure is a relic of small tuyer area, in a single course, of coal as fuel, of false economy in buying a fan blower so small as to require excessive speed to deliver the required volume, or a rotary blower so proportioned to the cupola that high pressure is inevitable, and above all, of forcing the cupola beyond the economical limit. It is no longer considered creditable to secure the largest possible output from a given cupola; it is better practice to use a larger cupola for the same output. The tendency is distinctly in the line of more moderation, both because of higher ultimate operating efficiency and the improved quality of the castings.

Figs. 8 and 9 clearly indicate the economy of such a course. It is to be noted that although the curve of maximum output in Fig. 8 is freely drawn through points representing gold current practice, it conforms closely to the relations expressed above, *i.e.*, that the melting rate varies directly as the square of the diameter. Wide variations are to be expected in individual cases. The maximum pressure capable of maintaining the corresponding melting rates under proper conditions vary with the diameter and the height of the cupola, as well as with the proportion of the charges. Other melting rates are plotted in proportion to the square roots of lesser pressures for corresponding cupola diameters. It is, however, because of the great variety in conditions that the values indicated by this or any other set are purely relative and cannot be made directly applicable to cupola practice in general.

TABLE III.

RANGE OF PERFORMANCE OF CUPOLA BLOWERS.

Diameter inside lining. In.	Capacity per hour. Tons.	Pressure per sq. in. Oz.	Volume of air per min. Cub. Ft.	Horse-Power.
18	0·25– 0·5	5– 7	150 - 300	0·5– 1·5
24	1·00– 1·5	7– 9	600– 900	2·0– 6·0
30	2·00– 3·5	8–11	1,200– 2,000	5·0– 15·0
36	4·00– 5·0	8–12	2,200 2,800	10·0– 23·0
42	5·00– 7·0	8–13	2,700 - 3,700	12·0– 32·0
48	8·00–10·0	8–13	4,000– 5,000	18·0– 45·0
54	9·00–12·0	9–14	4,500– 6,000	22·0– 60·0
60	12·00–15·0	9–14	6,000– 7,500	30·3– 75·0
66	14·00–18·0	9–15	7,000– 9,000	35·0– 90·0
72	17·00–21·0	10–15	8,500–10,500	45·0–110·0
78	19·00–24·0	10–16	9,500–12,000	52·0–130·0
84	21·00–27·0	10–16	10,500–13,500	60·0–150·0

The power economy of low pressures and melting rates is clearly shown by Fig. 9. The lines of unit expenditure have been arbitrarily fixed in the middle field of good practice.

The actual melting range of a cupola is ordinarily between 0·6 and 0·75 ton per hour per square foot of cross section. The limits of air supply per minute per square foot are roughly 2,500 and 4,000 cub. ft., with the mean as representative of fair practice. The possible power required varies even more widely, ranging from 1·5 to 3·75 h.p. per sq. ft., corresponding respectively to 2·5 and 5 h.p. per ton per hour for the melting rates specified above.

Current practice can only be expressed between limits as in the case of Table 3. Therein is given the ordinary range of the different variables for stated cupola diameters. The specified pressures prevail most extensively in recent installations. In so far as it is possible to determine the melting rate and the necessary pressure therefor, the power may be roughly calculated, from the theoretical requirement of 0·27 h.p., to deliver 1,000 cub. ft. per minute against 1 oz. pressure. The power increases directly with the pressure, and is practically dependent upon the efficiency of the blower. This will range from 50 to nearly 70 per cent. in a good fan installation, and up to a possible maximum of 90 per cent. with a first class rotary blower equipment. The drop in pressure due to an extended system of piping must not be neglected in such calculations.

The trend toward lower pressures in the cupola is reflected in current air furnace practice. The high pressure fan blower with small volumetric capacity has been superseded by the volume fan having ample capacity at much lower pressure.

Both volume and pressure are dependent upon the quality of the coal and the rate of combustion. The deep fire lends itself to complete utilisation of the air supply, with minimum excess and maximum temperature. Both under and over grate supply pipes should be of ample size to avoid excessive loss by friction, and the pressure should be the lowest which, with a properly proportioned blower, will pass the required volume. This pressure need not exceed 2½ oz. per sq. in., and under good conditions should be considerably less. The volume delivered beneath the fire may be kept well down toward the theoretical requirements, not exceeding 200 to 225 cub. ft. per pound of coal.

In the crucible furnace still lower pressures prevail, but the air supply is not as effectively utilised.

Flexibility in the application and operation of a blower is sufficient to permit of approximation in its size. Untortunately its size number conveys no idea of its capacity, although rotary blowers are secondarily classified by volumetric displacement. The manufacturer's recommendation, checked by the purchaser's experience, must generally serve as the simplest rule of selection. [Proceedings American Society Mechanical Engineers.]

The Chicago Underground Electric Freight Railway.

THE accompanying illustration shows a view of the subway recently constructed, and electrically equipped for transporting goods to various sections of the city of Chicago, in order to relieve the congestion caused by heavily loaded trucks on the streets of the city.

In New York, Paris, London and Berlin, the congested area has been relieved by the building of subways and tubes to take care of the passenger traffic, below the surface, and this has resulted in great benefit, providing at the same time a rapid transit system.

In Chicago, however, the relief of the congested area has been solved by removing the necessity of having large numbers of heavily loaded wagons and other freight vehicles hauled along the principal streets. By the use of this tunnel system the transportation of merchandise, coal, newspapers, packages, mail matter and other material is provided for entirely underground, a tunnel being built under an ordinance granted to the Illinois Telephone and Telegraph Company, by the city council of the city of Chicago.

It is stated that the business section of Chicago comprises about one and a-half square miles of territory, and is completely surrounded by the passenger stations and goods depôts of the twenty-five trunk lines, which makes Chicago the greatest railroad centre in the world. The goods handled daily at the freight depôts in Chicago amounts to more than 112,000 tons, and the present facilities afforded by the tunnel will relieve the congestion and facilitate the transaction of business in the business section, removing about 80 per cent. of the heavy teaming from off the streets. The walls are of concrete, and the tunnel is built egg-shaped. The walls are about 1 ft. thick, with a bottom somewhat over a foot in depth. They are 72 in. wide and 78 in. high, inside measurement, and are at an average depth of 40 ft. below grade

The pneumatic construction system was used largely, although a number of thousand feet were constructed without the use of air. The work is pushed day and night, and the twenty-four hours are divided into three eight-hour shifts. The shift which goes to work at 4.0 p.m. is known as the driving shift; this shift is relieved at midnight by another shift that finishes the drive, taking out the bottom, and does the trimming. The day shift does the concreting. Extreme precaution is observed at every stage of the work. Half-hourly reports of the progress of the work are forwarded to the chief engineer's office, and any fluctuation of the air pressure or change in the nature of the soil is immediately reported to the chief engineer in person, who remains in touch with the work constantly.

The concrete tunnel has an advantage, it is claimed, over a brick one. There is said to be no chance for a settling of the streets. In using brick it is impossible to dig a tunnel so true that the brickwork will fit snug, consequently they are obliged to back fill with clay, or any other material that is handy; this leaves voids which tend to cause settlement. In the use of concrete it is necessary to tamp the concrete tight, to get a perfect bond, and in so doing it fills up every void, no matter how uneven, making it an impossibility for any chance of settlement. It is with just pride that the management can say that from the time the work started up to

[A preliminary article on this interesting subway, giving particulars of the gravity coal handling plants, appeared in Vol. XIV., p. 384.]

the present date, the company has not received one complaint of any damage having been done to the streets of Chicago, or adjoining property.

At present there have been more than 175,000 lineal feet of tunnel constructed. The system now reaches every passenger depôt and freight house, and connections are being made with these, as well as with the warehouses, wholesale houses, retail houses, manufactories, &c., as fast as the alterations necessary in the buildings can be made. The first railroad to make provision to use the subway was the Lake Shore and Michigan Southern, in their new freight house at Clark and Taylor Streets.

It is stated that during the months of April and May there were five miles of tunnel constructed under the streets of Chicago. During the month of April there were constructed 10,105 lineal feet, and during the month of May there were constructed 12,619 lineal feet of tunnel, with the necessary appurtenances to make it practicable to operate electrically propelled trains; such as rails, trolley system, permanent lighting, drainage system, &c. It is held that the construction of this number of feet, with the necessary intersections, by-passes, &c., in the time mentioned above, is something entirely out of the ordinary when it is taken into consideration that the general average in tunnel construction up to the present time has been at the rate of two miles per year, even under the best of conditions, and where the soil has been uniform.

LOADED ELECTRIC FREIGHT TRAIN AT STREET INTER-SECTION OF UNDERGROUND RAILWAY OF ILLINOIS TUNNEL CO.

In carrying out the work, it has been necessary during the past two months to excavate about 60,000 cubic yards of material, and manufacture and place into position about 35,000 cubic yards of concrete. All the excavated material was transported through the completed tunnel system and deposited at Grant Park, at which point it is being used for

filling, for the improvement of the park. In connection with the same there was transported through the tunnel about 1,500 cubic yards of excavated material daily from the following buildings: Heyworth Bldg., Majestic Bldg., Mandel Brothers, Marshall Field, and the new Edison Bldg.; and, in fact, all the new buildings being erected in the down town district are having their excavated material hauled by the tunnel company.

Owing to the fact that it has been the means of keeping a large number of teams off the streets, the transporting of excavated material and wreckage through the tunnel system has been more than beneficial to the public and the users of the streets of Chicago. The benefits to the community are many. as it already has been the means of removing a part of the congestion by doing away with teams which had previously been engaged in hauling refuse and excavatings from the new buildings, as well as keeping the streets free from dirt and refuse, which has always fallen off wagons engaged in this class of teaming.

Many structures have been built which extend 30, 40, or 50 feet below the street surface, in New York, Boston and Philadelphia, and such basements are now being built in Chicago, and will be available in a way more advantageous than in the above-named cities; since the floors of the sub-basements will be carried to the level of the subway.

On account of the many styles of buildings which are to be tapped, and the many purposes for which the tunnel is designed, it is a constant tax on an engineer's ingenuity, as no two buildings are alike, and each requires its own treatment. Where the tunnel connects with a building whose basement extends but one storey below the street grade, a turnout or by-pass is constructed leading from the main tunnel to the inside of the curb line, where it connects with a shaft leading to the basement under the sidewalk. Specially designed elevators lift the cars to the basement floor, where with the use of a turntable they can be shoved wherever they are desired. The elevators so far in use are tested to carry 30,000 lbs.

The permanent track has a gauge of 24 in., and the Illinois Steel Company 4¼ in. 56 lb. rail was adopted as the standard rail. The rail is fastened by U bolts to a specially designed cast-iron chair embedded in the concrete floor of the tunnel. The great number of crossings and switches in use, necessitated by all the street intersection turnouts or by-passes leading to the different buildings, made it imperative that this part of the track system be as near perfect as could be made. The crossings in use are all bolted to steel plates that extend over the entire crossing, and this is also embedded in the concrete floor. The switches are those known as the split switches, and the frogs are constructed the same as the right angle crossings.

Except at the inclines at the Lake Front, where the Morgan third rail system is used, the overhead trolley is used throughout. The third rail consists of a steel strip about ½ in. in thickness by 4 in. in width, clamped between insulated wood stringers laid lengthwise in the centre of the track. The rail furnishes not only the current for the locomotive, but the means of moving the locomotive also, for it is provided with an opening for cog-wheels which are pressed on to the axles. A 0000 figure 8 trolley wire is adopted as the standard, held in place by Porter and Berg's standard barn trolley hanger, placed 15 ft. on centre.

At all street intersections automatic section insulators are used, which enables the current to be cut out in any block during temporary repairs, without shutting off the current from any other part of the system.

The style of cars and electric locomotives used for this work is well worth considering, and is of great interest. On the incline at the Lake Front it was found advisable to use the Morgan B type of locomotive; while in the tunnel proper there are two types in use, viz.:

the Jeffrey's Standard M.H. locomotive, and the General Electric Standard L.M. locomotive. The weight of the Jeffrey locomotive is six tons, and is equipped with two 18 h.p. motors, while the weight of the General Electric locomotive is five tons, and is equipped with two 20 h.p. motors. The locomotives are of a low and compact construction.

The "Kilbourne and Jacobs," and the "Bettendorf" double truck cars are used. The cars are 12 ft. 6 in. in length over all, and 47 in. in width. They are of steel and iron construction throughout, and can be used either as gondola or a flat car, and every car is equipped with the Master Car Builders' coupler. The weight capacity of the car is 30,000 lbs. The double trucks are so built that the cars readily operate upon a curve of 15 ft. radius. At the present time the box cars are equipped with the "Newman" patent dump box, which has a capacity of 3½ yards. The number of locomotives and cars now in use is large and is rapidly being increased.

Electricity is used for lighting the tunnel, the current for both light and power being supplied at present by the Chicago Edison Company. Power for the trains will eventually be furnished by a 5,000 h.p. generating plant; direct current at 250 volts, the rails furnishing the return, is the system now in use.

A tract of land on the Chicago River at 24th Street has been leased by the Tunnel Company from the North-western University, where the company is erecting its own power-house. The company will also erect large warehouses, where it will be possible for merchants, who only have a limited amount of space, to store a large supply of goods, drawing upon the same as needed. These warehouses will be erected on the company's own property on the west bank of the river at Taylor Street.

At each street intersection of the tunnel there is an automatic telephone. The cables for the telephone system are hung from the roof of the tunnel with a specially-designed adjustable strap. Guards are stationed at street intersections, and every precaution is taken to avoid accidents. The many connections already made with the tunnel insures thorough ventilation. The floor of the tunnel is dry, and as smooth as the average cement pavement.

At the present time the tunnel system extends from Indiana Avenue on the north, to 15th Street on the south, and west as far as Halsted Street, and is rapidly being extended beyond those limits.

New Graving Docks and Shipyard at South Bank-on-Tees.

An important ceremony took place on the 22nd October last in the formal laying of the first coping stone of the new graving docks and shipyard which Messrs. Smith's Dock Company, of North and South Shields, are laying down at South Bank on the River Tees.

The ceremony, which was carried out by Sir Hugh Bell, Bart., the chairman of the River Tees Conservancy Commissioners, marked an important stage in the development of the River Tees; as the new docks will add considerably to the docking and shipbuilding facilities of the port.

Forty or fifty years ago the river was navigable by only the smallest vessels; in fact, it is stated that at low water it was only with difficulty that a boat

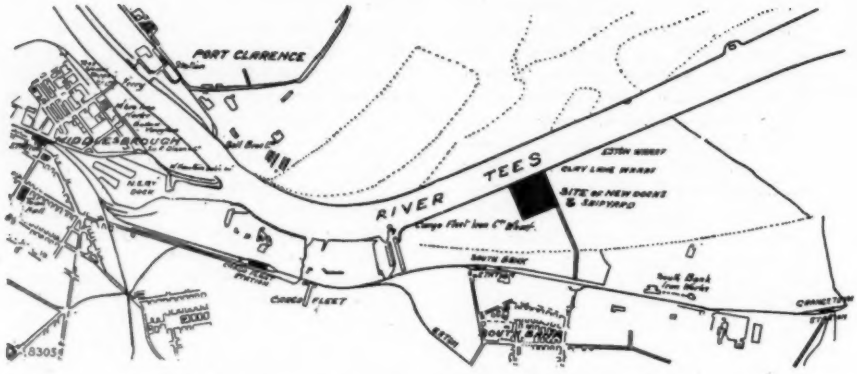


FIG. I.—MAP SHOWING THE SITE OF THE NEW DOCKS AT SOUTH BANK.

drawing ten inches of water could get down the river. The establishment of the furnaces of Bolckow, Vaughan & Co., at Middlesbrough, and of Bell Bros. at Port Clarence, and the development of the iron trade and shipbuilding in the district, however, called for improved facilities both in the direction of accessibility by river and in docking accommodation. These were carried out to the extent that the navigable channel was vastly improved, and artificial banks, breakwaters and docks constructed, among the latter being a graving dock constructed by the Tees Conservancy Commissioners. For a number of years, however, the Commissioners' dock has been incapable of dealing with the vessels frequenting the river, which have increased in numbers and dimensions by reason of the enlargement of the accommodation and the shipping facilities in the district and of the increase in trade in the Tees district. Hence the main purpose of the new works is to provide a thoroughly up-to-date ship-repairing dockyard capable of accommodating the heaviest tonnage and thus obviate much valuable repairing work being diverted to the Tyne, Wear, and Hartlepool. Other reasons, however, influenced the Smith's Dock Company, who are carrying out the scheme, in their choice of site, amongst these being the existence of a plentiful supply of skilled labour and the proximity of some of the largest steelworks in the United Kingdom. The chief incentive, however, was the absolute need for an outlet for a rapidly increasing business, as, notwithstanding considerable extensions of their yards on the banks of the Tyne at North and South Shields, which includes six large graving docks, two large pontoon docks, and a shipbuilding yard, it has been difficult to cope with the work which, besides the ship-repairing business, includes the construction and equipment of light draught cargo vessels, steam trawlers and drifters, steam tugs and ferry boats, and other small vessels of special types.

Hence in deciding on the construction of two large dry docks on the Tees, the company further decided to remove the whole of their shipbuilding yard to South Bank, so as to afford the necessary room for the above-mentioned extensions. The site shown in the accompanying map was provisionally chosen, but prior to its absolute purchase negotiations were carried on with the Cargo Fleet Iron Company, Ltd., from whom an option was obtained to enable the suitability of the ground to be thoroughly tested by borings. A large number of tests were carried out, with such satisfactory results that the company in March last year exercised their option and a contract was entered into with

Sir John Aird & Co., Westminster, for the reclamation of the land and construction of the works. The wisdom of the precaution of preliminary borings has been amply justified by the comparative certainty with which the works were designed and by the rapid manner in which the work of construction has already been pushed forward. Generally speaking, the banks of the River Tees render the construction of dry docks in an economical manner a difficult matter, but the site purchased by Smith's Dock Company is one of the few places where such works can be favourably dealt with.

The whole area was covered at most stages of the tide by several feet of water, the average level of the surface being about nine feet above low water level of ordinary spring tides. At low water the area was, as will be seen in Fig. 3, an expanse of mud.

The extent of this area is about 16¼ acres, with a river frontage of 800 ft., and it lies in immediate proximity to the Clay Lane Wharf of Messrs. Bolckow, Vaughan & Co.

The first operations of the contractors consisted in the reclamation of the site, for which purpose a cofferdam, some 2,000 feet in length, was constructed of timber sheet piling suitably braced and strutted. Ten pile-driving engines were employed, the piles being driven to an average depth of 17 ft. below ground level. Although the quantity of leakage was very small, the piling was strengthened by a bank composed of slag and earth filling, extending the whole length of the dam, inside and out, to a total

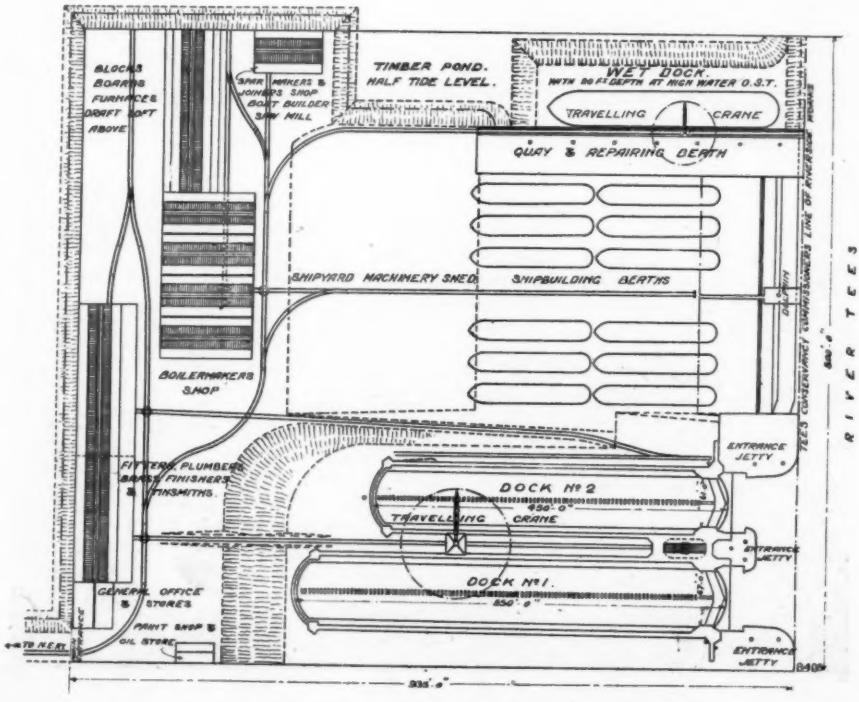


FIG. 2.—PLAN OF THE GRAVING DOCKS AND SHIPYARD AT SOUTH BANK.

width at the base of 27 ft. The construction of the two large graving docks and the earth filling necessary to bring the dockyard half of the site up to the finished level is now being actively proceeded with and is to be completed on or before the 1st of November, 1908. The two graving docks will be of the most modern description, and even as at first constructed, will be capable of accommodating the largest vessels frequenting the River Tees. The leading dimensions are: Dock No. 1, 550 ft. long, 67 ft. wide between entrance walls, and 26 ft. deep upon the sill at high water of ordinary spring tides; dock No. 2, 450 ft. long, 61 ft. wide between entrance walls, and 26 ft. deep on the sill, h.w.o.s.t. Although well able to accommodate the largest vessels at present frequenting the Tees, provision for extension is, however, being made in the construction of these docks. The inner ends have been designed in such a manner as to allow of their being moved further in if it be found desirable to lengthen the docks in the future. For this purpose the landward ends are to be of timber construction, supported by steel arched ribs, thus enabling the whole to be moved further in. Ample height of blocks in the dock floors is also being provided, as the dock floors will be 4 ft. 6 in. below the level of the sill, thus giving plenty of headroom to workmen engaged on the ship's bottom. It may also be pointed out that the width of the dock is considerably greater than that between the entrance walls, thus allowing ample working room.

The pump room and suction will be placed near the entrances and between the two docks so as to command either or both. The pumps will be of very large size, and will be capable of emptying the larger dock at high water

FIG. 3.—THE SITE ON JANUARY 30TH, 1907.

FIG. 4.—VIEW SHOWING THE PROGRESS OF THE WORKS.

when containing about 36,500 tons of water in 90 minutes. They are to be electrically driven, power being supplied by the Cleveland and Durham Electric Power Co. The Worthington Pump Co., Newark, and the Westinghouse Co. have the manufacture of this plant in hand, comprising two 400 h.p. three-phase induction motors, operating at 40 periods, 400—440 volts at 285 revs. per min., and one 35 h.p. three-phase induction motor of the squirrel cage type, operating with the same periodicity and voltage at 700 revs. per min.

The new shipyard adjoins the coffer-dam enclosing the docks, and when the site is reclaimed and properly laid out, it will allow of the simultaneous construction of from 12 to 18 trawlers of the largest class. The shipyard will have a frontage of 800 ft., and a 32 ft. depth of water along its full extent at h.w.o.s.t. At this length of quay vessels will be completed or repaired afloat. There will also be accommodation for timber, while on the west side of the shipyard the scheme includes a gut, or wet dock, lying parallel to the dry docks, having a depth of water of 20 ft. at h.w.o.s.t., which will provide further berths for vessels under repairs. The workshops will be commodious and up-to-date, and so arranged as to facilitate the rapid handling of materials, from one department to another. All the buildings — machinery sheds, fitting shops, boiler shops, smiths' shops, painters' and boat builders' shops, moulding lofts, drawing office, and general offices—have been arranged to afford the maximum of comfort and convenience. The whole of the plant on the works will be driven by electrical power, also supplied by the Cleveland Electric Power Company. Adequate

provision for access to the works has been made.

The company will have their own roadway leading to the Cargo Fleet Company's road and level crossing across the North-Eastern Railway, and this road will in the future be supplemented by a new road which the South Bank Urban District Council propose to make from the N.E.R. crossing down to the river. The railway connection with the N.E.R. will place the works in communication with every part of the country.

The progress of the works so far has been excellent, and although the date of the commencement of the contract was the 2nd of January of the present year, the cofferdam was completely constructed and closed on the 27th of April. Up to the present time nearly one-half of the total of 140,000 cubic yards has been excavated; the foundations of the large suction well under the pump room have been excavated; the concrete of the suction well floor is already in place, and the dock walls on either side of it are making steady progress. The concrete work of the two outer walls of the two docks is in progress for almost their full length, and the walls are being built rapidly upwards, the concrete for the greater part of the length of the trenches excavated varying in height from over 13 ft. to over 30 ft. above foundation level. The dock floors and pump room walls are reinforced by means of ordinary 70 lb. steel rails, while the pump room floor will be strengthened by rolled steel joists. A large amount of filling has been carried out over the site of the dockyard. The filling of the road leading to the site has been almost completed; the filling of the shipyard is in progress; the dock gates have been made ready for sending on to the site for erection. The latter are by Messrs. Head, Wrightson & Co., Ltd., Thornaby, and are of steel, following the usual construction with buoyancy chambers. There will, however, be no supporting rollers, the weight being taken by a pivot bearing and top anchorages. The emptying and filling culverts consist of 54 in. diameter cast steel pipes, the six former with electrically operated sluice valves by Glenfields, Ltd., and the three latter with special equilibrium valves.

With the object of bringing all the work to a simultaneous finish the Tees Commissioners are about to remove the lighthouse immediately opposite the new graving dock entrances to a position a few hundred feet further up the river, and to increase the width of the river on the north bank by about 220 ft. for a distance of 600 ft. by setting back the low water training wall on the opposite side of the river, thus enabling large vessels to enter and leave the docks without impeding the river traffic. The entire length of 800 ft. will also be dredged to 15 ft. below l.w.o.s.t. The whole cost of the works when completed is computed to be £250,000.

The firm of Smith's Dock Co., Ltd., to whom the carrying out of this enterprise is due, although under its present name dating only from 1891, is really of very old standing, consisting as it does of the amalgamation of the firm of T. & W. Smith, founded in 1782, with the firm of H. S. Edwards & Sons, founded in 1768, both firms having been engaged in the repairing of vessels on the River Tyne for the whole period of their existence, and in the bui ding of new vessels during more or less of that time. Representatives of the two families connected with the original firms are at the present date actively identified with the present company, the chairman being Mr. Jas. H. Edwards, and the managing director being Mr. Launcelot E. Smith.

The designs for the undertaking have been prepared by Mr. J. Mitchell Moncrieff, M.Inst.C.E., of Newcastle-on-Tyne, whose resident engineer is Mr. Jas. Mitchell, A.M.Inst.C.E., Mr. G. F. Palmer acting for the contractors, Messrs. John Aird & Co.

ELECTRICAL PROGRESS

By ANDREW STEWART, A.M.I.E.E.

Electrically Operated Rolling Mills.

We have from time to time reviewed the work done in this direction, though hitherto examples of non-reversing mills only have been found in England. One has to go abroad for examples of reversing mills of large size. One of the largest visited by the Iron and Steel Institute during their Vienna meeting was at Trzynietz, in Austrian Silesia, where there are, among other things, a reversing mill of over 10,000 h.p. and a non-reversing mill of 750 h.p. There is a fly-wheel converter which takes the fluctuations of the load, this converter taking only a steady 1,000 h.p. to drive it. The violent fluctuations which take place when reversing, and when the metal enters the rolls, are taken up by the flywheel.

A somewhat similar plant is now being erected in England, Messrs. Dörman, Long & Co. having decided to equip their plate rolls in the new Cleveland Wire Works with electric motors, power to drive them being purchased from the Cleveland and Durham Electric Power Co.

The rolls will be driven by a 4,000 h.p. motor running at 110 revs. per min. The current for this rolling mill is supplied from a flywheel converter, which consists of a 950 h.p. three-phase motor, driven by current from the Power Company's mains. This motor drives a 4,000 h.p. direct-current generator, and between these two machines is a heavy flywheel capable of giving out, with a small reduction in speed, as much as 3,600 h.p. for a few seconds, sufficient to take the surge of current which is required for the mill motor when it is reversed, and when the metal enters the rolls.

There can be no doubt about the ultimate success of the plant, in view of the success of much larger equipments elsewhere; and like the electric driving of cotton mills, the first of which has only been in operation about a year, yet has been so rapidly succeeded by similar equipments, that some electrical firms have come to regard such equipments as the mainstay of their business.

It is not too much to hope that there will be a similar epidemic of electrification in rolling mills; but there is this difference: we are on the eve of a steady diminution in the volume of business in many industries, and the falling off in the demand for steel for shipbuilding may check the inclination of steel works owners to electrify, though after all, the time to improve the equipment is when there is a tendency towards dulness, so that radical changes of this kind cause a minimum of inconvenience, and prepare the works to cope with the boom that is sure to follow.

An Electrically Operated Aerial Ropeway.

Perhaps one of the most interesting aerial ropeways in the world is that just completed over Lake Michigan. Lest it should be thought that this is a form of transport peculiar to America, it may as well be pointed out that there are several such lines in this country, chiefly in Cleveland, Durham, and Lancashire, where they are used to transport coal and iron ore, often over considerable distances. In this case the aerial ropeway is for the purpose of transporting men and material to and from the inlet to the tunnel which is to supply a part of Chicago with water.

The inlet to this tunnel is 1½ miles from the shore, and the problem of taking the construction machinery to this point, and subsequently removing the excavated material, was solved by the construction of the cableway, a view of which is shown

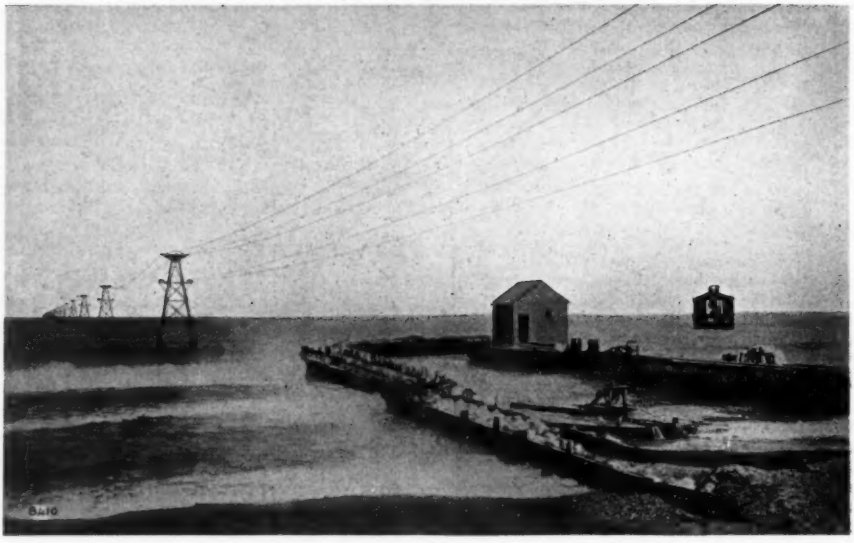


FIG. 1.—CABLEWAY OVER LAKE MICHIGAN.

FIG. 2.—TOWER AND CABLE CONSTRUCTION AT SHORE END OF CABLEWAY.

in Fig. 1. The top cables seen in the illustration support the cars, one of which is seen suspended in Fig. 2. The cable on the lower arms is a continuous cable for haulage, the gripper being merely a modification of that seen on cable cars, this being placed above the car and seen clearly in Fig. 3, which illustrates one of the passenger cars. There are, of course, a large number of skips for dealing with excavated material.

The towers are 30 ft. above the surface of the lake, and spaced 300 ft. apart; the greatest depth of water in which they stand is 30 ft. The cable is hauled by a 25 h.p. induction motor, operated by current taken from the city mains. The haulage cable is of course always in motion. The cars start by merely gripping on to the moving cable.

FIG. 3.—PASSENGER CAR.

Some Gas Engine Performances in Electric Power Stations.

Among the papers read at the Annual Convention of the American Street Railway Association was an interesting contribution to this question by Mr. Paul Winsor, Chief Engineer of Motive Power, Boston Elevated Railway, who speaks from experience of steam and gas driven plants. In considering the results, excellent though they are, it must not be forgotten that the plant is relatively much smaller than the steam plants operated by the same company, so that they are probably not quite the best the gas engine can do.

The plant consists of two 600 h.p. two-cylinder "Crossley" gas engines working on producer gas, and driving 350 kw. "Crocker-Wheeler" dynamos. It has been in operation since May, 1906, and there have been no failures to supply and no accidents.

For the first seven months of 1907 the coal used per kw. hour averaged 2·034 lbs., against 3·377 lbs., the average of their steam stations. Taking, however, a steam station of similar size to the gas engine plant, the fuel consumption was 4·414 lbs. In other words, the gas engine plant showed in comparison with a much bigger steam plant a saving of 40 per cent. in fuel, and if compared with a steam plant of about the same size a saving of 53 per cent. in fuel is possible, figures which are sufficient to justify a careful consideration of the question of such prime movers where coal is at all expensive; and this notwithstanding all that has been said about Johannesburg and its gas engines, where failure seems due not so much to engineering considerations as to other, and at present more obscure, commercial matters.

A problem of no small importance in the case of this Boston station, and, curiously enough, one which played some part at Johannesburg, is the altogether unexpected supply of water required for scrubbing the gas and cooling purposes. This amounts to 281 lbs. per kw. hour, and as the company at first had to purchase water, this item cost twice as much per kw. hour as fuel did. A year ago, however, a motor driven pump, pumping water from a dirty brook, was installed. These pumps drove the water through a filter, and then to the scrubber and engine cylinder.

The water discharged from the scrubber was even worse than that in the brook, and this is now filtered, and the water goes into the brook much cleaner than it came out. The cost of pumping and filtration is a very small amount.

As to reliability, the units can be brought into operation in five minutes, and take considerable overloads. For instance, there are several cases of loads of not less than 652 h.p. for an hour, with occasional rises to 717 h.p., equal to an overload of 20 per cent. As small overload capacity is one of the disadvantages of the gas engine, the foregoing is interesting, though probably it represents about the upper limit of an

engine which is rated at or near its most economical load.

As to capital cost, this is of course a point of considerable importance, as capital charges are a serious item in the cost of producing electrical energy. Mr. Winsor puts this at £40 per kw. installed (1½ h.p.) when the plant is rated to allow of 33⅓ per cent. overload capacity, apparently referring to a small plant such as described, and to American prices, which are higher.

Maintenance Charges on London Underground Railways.

A short time ago we referred to some of the causes which contributed to the unsatisfactory position of the District Railway since the electrification of its lines. As we then pointed out, track and rolling stock renewals accounted for a very large amount of money. It appears now that, on some curves, the rails have to be renewed so frequently that the average over a period of years may work out at complete renewal every nine months or so. Re-ballasting over the entire system has been necessary owing to the higher speeds of the rolling stock, and the latter seem to be rapidly swallowing, in repairs, the money saved on its original cost; this repairs item is much lower on the Metropolitan, where more expensive and solidly constructed British-made stock is used. Even the passengers notice the difference between a journey on the two lines. Unfortunately, the District Railway, being under the eye of many railway directors, and others interested, proves of negative value as an example of railway electrification, for its want of financial success is frequently quoted as a reason why electrification should be deferred. The real cause of its non-success, viz., a penny wise pound foolish policy, much more characteristic of American than of British methods, is no fault of the motive power at all.

An Unexpected Development in Railway Electrification.

Mr. Harriman, one of the best known American railwaymen, said some time ago that trunk lines would be electrified, not primarily to secure greater economy, but simply because the rapidly growing trunk line traffic would soon reach a limit beyond which it could not go, because the steam locomotive is rapidly reaching the limit of its power, and further increases in the size of the engine could not be effected owing to the limits in the loading gauge. This limitation is more severely felt in this country than in America, and if longer and heavier trains cannot be handled by steam locomotives, and the traffic is as dense as working conditions permit, the duplicating of the line is inevitable.

It appears that something like this state of affairs has been reached on at least one section of the Southern Pacific Railway, where the line crosses the Sierra Nevada Mountains from Rocklin to Sparks. This trans-continental line carries very heavy traffic, and apparently has immense earning power, which, however, is throttled by the inability of the steam locomotives to handle the traffic. So serious is this, that at times an absolute block occurs, notwithstanding the fact that the locomotives, which, by the way, burn oil fuel, are among the largest and most powerful constructed.

The problem is no easy one, as the section between Rocklin and Sparks is 136 miles long. It includes gradients of 1 in 40 over the Sierras, and the line rises 7,000 feet in 83 miles. It is single track; there are 31 miles of snowshed and tunnelling, and the problem of doubling the track is one which the engineers of the company seem disinclined to face, until all other expedients have been exhausted.

Mr. Frank J. Sprague has been asked to join the electrical engineer of the railway company in studying the problem of electrification, and prepare a scheme for electric traction on this section. It is felt that an electric locomotive, unhampered with the generation of power, but depending merely on the collection of current from an external conductor, with all the resources of a large power house to draw upon, will more readily deal with these heavy train loads than the present steam locomotives, powerful though they undoubtedly are. Any other expedient, such as doubling the track, would cost much more, and it is felt would merely delay, and not render unnecessary, a change in motive power.

FOURTH PRIZE COMPETITION.

For Works Managers, Foremen, Machinists, etc.

See Last Page.

Iron, Steel and the Foundry.

Conducted by PERCY LONGMUIR.

FOUNDRY PRACTICE.

Melting Iron for Castings.—In the October *Foundry*, Professor Bradley Stoughton discusses several aspects of cupola practice. The design and principle of operation of the cupola furnace has a certain similarity to that of the blast furnace, the chief difference being that the coke of the cupola is desired only for its melting influence, and the only chemical reactions are minor and unintentional. The cupola gives the cheapest method of melting, because there is direct contact between metal and fuel, and therefore the maximum absorption of heat. After detailing the familiar features of the cupola, the author passes on to a consideration of its working.

The blast pressure will depend somewhat on the size of the cupola; but the present practice is in favour of pressures not exceeding 1 lb. for the largest cupolas, and diminishing to ½ lb. or so for smaller sizes. The common type of blower used in America is of the two impeller type. As some 60 cub. ft. of air are required to burn 1 lb. of coke, the size of the blower for each cupola may be calculated, giving an additional allowance of from 50 to 100 per cent. excess in order to cover leakage and incomplete combustion. With too large a volume or too great a pressure the melting zone is raised, which necessitates a greater depth of bed coke in order to reach the upper level of the melting zone, and is therefore wasteful. The molten iron has also a greater height to drop through, and the oxidation is therefore greater. The volume of blast is the most important consideration, but this is difficult to measure, so that pressure is the factor entering into calculations.

In discussing chemical changes sulphur naturally takes the first position. The actual increase depends chiefly upon the relative amount of coke and iron used and the content of sulphur in the coke. The usual range is from 0·02 to 0·035 per cent.; thus, if the charge contains 0·08 per cent. sulphur, the castings will vary according to the amount absorbed from 0·10 to 0·115 per cent. Sulphur in the first iron is usually higher than in that of the middle of the run, because of the extra amount of coke burned before the iron begins to run from the tap hole. The last iron will also be somewhat higher in sulphur, because there is a greater loss of metal during the last of the run, when the oxidising conditions are more intense, and therefore a concentration of sulphur. The best practice is to cut off blast progressively as the material in the cupola diminishes. As the metal melts and falls from the melting zone down in front of the tuyeres, it is subject to oxidation, which carries iron oxide into the slag and also some of the silicon. The melted metal will contain from 0·25 to 0·40 per cent. less silicon than the original charge. However, with good practice the loss should not be more than 0·30 per cent.

Melting losses vary from 2 to 4 per cent., and are made up of the silicon and iron oxidised and passed into the slag. Other sources lie in second loss due to remelting runners, &c., and metal spilled during pouring. The total loss, that is, difference in weight between pig iron bought and castings made, will range from 7 to 8 per cent.

Sandless Moulds for Malleable Cast Iron.—Dr. Moldeuke gives a note in the October *Foundry* detailing tests made in this direction. Some years ago, when making speciality work weighing 300 lbs. per casting, it was determined to try the sandless process. An iron mould was made and so arranged that it could be easily opened to remove the casting quickly. The castings, being 3 ft. long and having a projection at one end, required the insertion of a core, which would readily crush as the metal contracted, and until this was arranged the castings invariably pulled apart. After

repeated failures, persistent work brought success, and some 800 of the castings went into actual service. The experience gained leads the author to offer the following suggestions. The heavy contraction found in white iron necessitates close watch, in order that the iron may draw together evenly and without strain. Hence the use of cores where necessary, or the limitation of the method to straight work. Next, it is necessary to heat the mould to almost a dark red heat before casting, and then it should be filled as often as possible in order to maintain this temperature. The castings should be removed immediately on solidification and covered with sand in order to cool slowly. Tests made on the castings thus produced showed a tensile strength of some 38,000 lbs. per sq. in. This was about 2,000 lbs. per sq. in. lower than the regular metal, and the abandónment of the method due to shop opposition caused the matter to rest there, for doubtless some way would have been found to correct this reduction in strength. However, the metal made would be considered good enough for general purposes. It may therefore be said that where many castings are to be made, their production in sandless moulds has a future, and needs only intelligent application to be a success.

Use of a Heated Foundry Mixer.*—Mr J. B. Nau, who has previously advocated the use of mixers in connection with foundry work, describes steps being taken to achieve this end. A foundry is being erected in connection with a blast furnace plant, and the daily output at first is expected to be from 25 to 30 tons of very small castings. Owing to the limited output, a high priced tilting mixer was out of the question. It was therefore decided to build a stationary furnace of the Siemens type with a short and deep hearth and air regenerators of a capacity sufficiently large for the temperature desired in the mixer. In order to avoid the operation of gas producers oil was adopted as fuel. The rated capacity of the mixer is only 25 tons, and owing to the small size of the castings it will have to be tapped and stopped many times during the day. Several tap holes are therefore provided, and the upper ones will be drained before opening lower ones. A mixer of 25 tons capacity is, however, large enough to supply a foundry of 100 tons capacity, the principal rôle of the mixer being to receive the direct metal from the blast furnace in large quantities during the day, and whilst keeping it hot and correcting its quality by suitable additions, to withdraw in repeated and smaller taps whenever required in the foundry.

* American Foundrymen's Association.

British Foundry Practice.—Mr. W. G. McIntosh gives his impressions of British practice in a paper read before the Cincinnati Foundrymen's Association. On the whole, these impressions are exceedingly good, and the author has caught the spirit of British practice very clearly. Starting with the statement that even in America one foundry differs in glory from another, as do the stars in heaven, so in this instance of comparative British practice. Moulding methods are surveyed, note being laid on the absence of wooden boxes, the predominance of bedding in, and the wide application of loam moulding. Cupola practice is very much on the same lines as in America. While many foundrymen depend entirely on fracture for judging the quality of pig-iron, together with traditional information, other concerns have a chemist or metallurgist who works in conjunction with the foundry foreman. The only fluttering of the Eagle's wings is in the following paragraph, and, as it is always well to see ourselves as others see us, we give it in full. "England being an old country, it is only to be expected that the American visiting its foundries, especially in the country districts, where the population is not so cosmopolitan, will find many things that would cause him to smile, inasmuch as some of them climb the fence as their forefathers did, believing it to be the only and best way of doing things. They are prejudiced against new ideas and methods, which they look upon with superstition, and consider putting them into practice almost sacrilege. The American, on the other hand, does not confine himself to local help, for he is aware that many a man who has travelled in various shops knows more than one who has not, and may be able to greatly increase his output and profits. It is no unusual thing to discharge a man, in Britain, who presents new ideas or suggestions, even though their benefits or values are inevitably and readily made manifest. Although I say it is not an unusual thing, I would not have you conclude that this characteristic is universally prevalent by any means, but it would be more profitable to British manufacturers, as well as more satisfactory and encouraging to the employee, if the man at the head of affairs, instead of being so autocratic and conservative, were more approachable and receptive."

Semi-Steel Castings.—Mr. D. McLain gives his experience of this product in a

paper read before the Milwaukee Foundrymen's Association. Many troubles were encountered, and the rejections on test ran high. The analysis of these castings ran as follows:—Silicon, 1·25 to 1·74 per cent.; manganese, 0·44 to 0·77 per cent.; phosphorus, 0·54 to 0·65 per cent.; and sulphur, 0·094 to 0·155 per cent. The character of the metal was altered by increasing the manganese, which in turn effected a reduction of sulphur, and resulted in extremely successful results. These alterations gave a metal of the following analysis: Silicon, 1·65 to 1·75 per cent.; manganese 2·0 to 2·5 per cent.; phosphorus, 0·45 to 0·50 per cent.; and sulphur, 0·04 to 0·05 per cent. In calculating a mix for semi-steel, the pig iron selected runs about 0·35 to 0·45 per cent. phosphorus; 0·025 to 0·035 per cent. sulphur; and manganese, 1·0 per cent., or higher. Silicon varies, but as the amount of silicon determines the percentage of steel, this is the only point to watch. Thus, if the silicon runs 2 per cent., the iron will carry 30 per cent. steel; if 2·25 per cent., then 35 per cent. steel, and so on, always aiming for a content of silicon of from 1·65 to 1·75 per cent. in the casting. Manganese is added in the form of ferro-manganese to give from 2·0 to 2·5 per cent. in the casting.

STEEL: ITS PROPERTIES AND TREATMENT.

The Effect of Vanadium in Steel.—In the *Iron Trade Review* Mr. E. T. Clarage gives an interesting description of vanadium and its effect in steel. Some of the reasons advanced are possibly open to discussion, but in any case they are well worth examination.

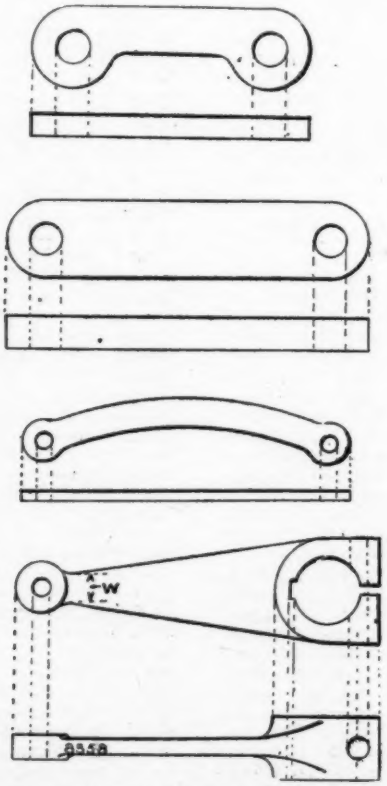
Sulphur and phosphorus have long been recognised as the two deadly enemies of steel, but metallurgists are beginning to realise that other elements may be more injurious. Oxygen and nitrogen may be present in small quantities, and the presence of either one has an exceedingly injurious effect on steel. As a rule analysis will show the largest amount of nitrogen in Bessemer steel, a smaller amount in open hearth, and lowest in crucible steel. This is probably the reason why a crucible steel is superior to the best open hearth steel, even though carbon, manganese, silicon, phosphorus, and sulphur may be the same in each. Vanadium will combine with oxygen and nitrogen at high temperatures, and thereby acts as a cleanser in eliminating these gases. The presence of even one-tenth of 1 per cent. vanadium in the finished steel is a guarantee that the nitrogen has been separated from the steel. The effect on oxygen is the same, but this is not nearly so important, in that other and less expensive material, such as manganese and aluminium, may be used successfully as dioxidisers. In addition to its cleansing effect, vanadium has a noteworthy influence on the physical properties.

In regarding vanadium from the standpoint of the tool steel maker, the author notes in the first case that experience has shown that certain brands of Swedish iron make the best steel. Whilst it is possible to obtain American irons of equal purity to Swedish, it is also recognised that these irons will not produce the same quality of tool steel. The old steel maker will say that Swedish irons have "body," and it is a fact that even a few pounds of these irons used in American brands will have a noticeable "toning-up" influence. Langley, in an exhaustive study of this subject, found that the best Swedish irons were practically free from nitrogen, which was always present in American irons. As this was the only difference found, Langley concluded that nitrogen was responsible for the different results. In the light of present developments it is evident that vanadium is responsible for this absence of nitrogen. In support of this the author quotes various authorities who have shown the presence of vanadium in either Swedish refinery slags or in the iron. It is well known that a low grade tool steel deteriorates more rapidly under successive hardenings than a high grade product. The process of hardening is a tremendous shock to the material, as a result of the sudden contraction. An important result from the use of vanadium is that the resistance to dynamic stresses is greatly increased. Therefore a tool steel made from these Swedish irons, which contain even traces of vanadium, will considerably outlast the ordinary low-priced tool steel. Vanadium has other properties which may make it eventually a substitute for tungsten in the manufacture of high-speed steel, when the cost is such that it can be used in larger proportions.

Steel Hardening Metals.—An editorial comment in the *Mining World* draws attention to the influence of steel research in stimulating prospecting for ores in the United States. The known steel-hardening metals named in the order of importance of production and use are: nickel, chromium, manganese, tungsten, molybdenum, vanadium, titanium, cobalt and uranium. The value of these metals produced in the

United States in 1906 amounted to $458,327, of which $393,667 was for tungsten. The price of tungsten, which has been increasing for a number of years, was quoted at $5 to $6 per unit in 1905 and at $12 per unit in the spring of 1907. Only small quantities are at present imported into the United States, as European markets utilise all that is produced. Large deposits of tungsten are found in Australia, and it is not improbable that sufficient may be obtained there to permit of a certain portion of it being shipped to the United States, but for the present this country will have to look within its own borders for sources of supply.

Acid Open Hearth Slag. — Mr. W. M. Carr gives a note under this heading in a recent issue of the *Iron Trade Review*. The composition of an acid slag is made up of sand adhering to the pig iron, hearth scorification, oxidation of the manganese and silicon present in the charge, and oxidation of the iron by flame action. The volume of the slag will vary with the character of the charge, the nature of the fuel, the additions of iron ores, and the manipulation of the heat. The slag is regarded as a ferrous silicate, and consists of nearly equal parts of silica and ferrous oxide. Should manganese be present in the charge, its resultant oxide will replace some of the ferrous oxide, but the sum of the two oxides will nearly equal that of the silica. With normal conditions the fluidity of the slag and its requisite composition is practically automatic, and it is unusual for an acid open hearth slag to need readjustments by outside agencies.



FIGS. 9 TO 12.—A HANDY PROFILING RIG (see opposite page).

Workshop Practice

OUR THIRD PRIZE COMPETITION.

RESULT.

After carefully considering the papers submitted in connection with the Third Prize Competition, the prizes have been awarded as follows:—

PRIZE OF £5.

Mr. H. G. Williams,
Worting Road, Basingstoke.

PRIZE OF £2.

Mr. J. Pollock,
Linwood, Nr. Paisley, N.B.

PRIZE OF £1.

Mr. W. Duckitt,
Pershore Road, Birmingham.

In addition, the Editor has decided to award a consolation prize of £1 to

Mr. M. M. Sharp,
Wickham Lane,
Plumstead, S.E.

We commence the publication of the prize papers on this page. In the meantime we are announcing another competition, for particulars of which see page 444.

A Handy Profiling Rig. — The sketches, Figs. 1 to 8 and 13, show a profiling attachment for a hand milling machine which I got out recently for milling levers and links, similar to those shown in Figs. 9 to 12 (page 408). Parts of this description are frequently met with, especially in connection with automobile manufacture. Although apparently simple, the cost of machining them is at times considerable, while the resulting finish—unless skilled labour is employed—is often far from satisfactory. This, at least, has been the experience of the author, and was the reason for designing the attachment here shown. The machine to which it is adapted is one of the least expensive it is possible to obtain, and is worked by a raw apprentice. Referring to the sketches, Fig. 1 is an elevation of the machine with attachment fixed in position, and with stops on rod *C* set for profiling a link, similar to that in Fig. 10. *D* is an iron casting, details of which are given in Figs. 2, 3, and 4, the view at Fig. 2 being a section through *XY*. A tongue in the base fits the tee-slot of the machine table. Two grooves, each 1½ in. wide by ⅜ in. deep, are planed through the whole length of the casting, the distance between the centres of these grooves corresponding to the distance between centres of *A* and the cutter spindle. *A* is a circular bar, the end of which is bored and screwed to suit a phosphor bronze bush, carrying a hardened revolving tracing pin, which is provided with a ball thrust, and is shown in section in Fig. 13. This bar was made of the same diameter as, and took the place of, the overhanging arm supplied with the machine for supporting the cutter arbors. Two circular formers *E* and *F*, two stud-blocks *G* and *H*, and studs with one end screwed to fit tapped holes in *G* and *H*, the other end being turned to fit the job in hand, complete the outfit. These formers and stud-blocks are shown in Figs. 5 to 8. It will be seen that one of each is arranged to take up a fixed position on the casting *D*, holes being drilled for this purpose in correct relationship with *A* and the cutter spindle; while the other two are made to slide in the grooves, and may be fixed in any position within the limits of the plate to suit varying lengths of levers or links. The lines shown on the formers are used for spacing them the same distance apart as the centres of holes in the work which is being milled. There are three stop rods on the machine, *B*, *C*, and

one at the back end of slide *K*, Fig. 1. These are all brought into use for different parts. In profiling Figs. 9 and 10, the stops on rod *C* are used in conjunction with the conical formers *E* and *F*. For Fig. 9 a second operation is necessary, in which the upper stop on *C* and the stops on rod *K* are used. The latter are also set for Fig. 12, determining the length of arc through which the cutter travels, or width at *W*. An inexpensive method of making the formers required for quadrants, such as is shown in Fig. 11, is as follows: The stock for former is attached to stud-blocks *G* and *H*; an angular cutter being used having the same angle as the tracing pin. The ends are machined by the same method as for Fig. 12. A quadrant the same length and radius as that required, but of even width and depth, is then turned and holes drilled, the distance between centres of these holes being the same as in the former or piece to be profiled. This quadrant is attached to the conical formers *E* and *F* by means of screws fitting the central tapped holes, and provides an accurate method for milling the central part of the former. By following similar methods, it is remarkable what a number of tedious jobs may be quickly disposed of; in fact, fresh uses for the attachment seem to be always cropping up. Several of the jobs done on this attachment have been got out in one third the time formerly taken. H. G. W.

Cutting a 9·25 in. Worm.—I had the opportunity a few months ago of supervising a job of such a nature that it required all

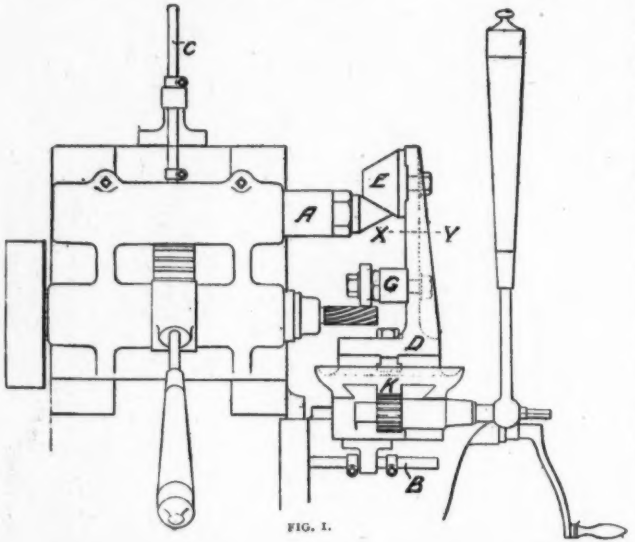


FIG. 1.

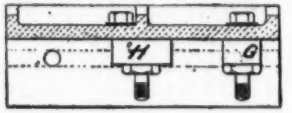


FIG. 2.

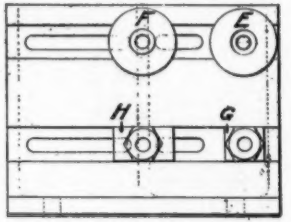


FIG. 3.

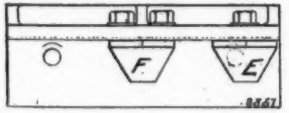


FIG. 4.

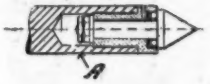


FIG. 13.

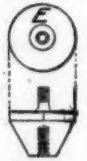


FIG. 5.

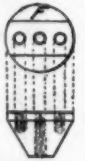


FIG. 6.

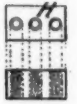


FIG. 7.

FIG. 8

A HANDY PROFILING RIG.

the theoretical training and practical skill I possessed to finish the task. It was none other than to cut a worm 9·25 in. diameter out of solid steel. The lead of the worm was 10 inches, and with five threads gave a 2 in. pitch. As we possessed no special machine for this class of work, such as a worm milling machine, we had no alternative but to turn our attention to a 12 in. screw-cutting lathe with a leading screw of ½ in. pitch. It was out of reason to attempt to cut such a worm by applying the power in the usual manner through the cone on the main spindle, as the ratio between the leading screw and the worm to be cut would be too large (20 to 1). There was bound to be a breakage in the train of change wheels, as the power was being applied at too great a mechanical disadvantage; but if it was within the range of possibility that the change wheels could withstand the strain exerted, the main spindle of the lathe, or, what is the same thing, the worm, being operated on, would revolve too fast for all practical purposes. The method I employed to overcome the difficulty may be gathered from Fig. 1, showing an end view of the lathe in question. By attaching a pulley *E* on the leading screw, and by removing the belt from the cone *G*, on the main spindle and placing it on the pulley *E*, we adopt on the lathe for the time being the method employed by modern milling machine makers, who use the same principle of driving from the screw through the change wheels to the spiral head. In the converted lathe the main spindle becomes a substitute for the spiral head. It should be noted in passing that the back gear of the lathe should not be in gear, as it would destroy the advantage otherwise gained.

The pulley *E* was keyed on the screw in line with the bottom step of the cone on the countershaft *F*. The maximum diameter of pulley I could employ was 9·5 in. and as the diameter of the countershaft was 7·25 in. it will be seen that I was working on very fine lines, for the larger the pulley *E*, the better the facilities to overcome work of this nature. This leads to a suggestion to lathe builders that they might overcome such a difficulty by a very slight alteration in the pattern of bed at that particular place, to admit of the use of a larger pulley. By such modification the advantages gained would be of paramount importance in universal lathe work.

The work under consideration was a worm of standard data with respect to pitch, so that the depth of thread was 2 in. × ·6866 = 1·373 in., the normal breadth at top of thread being 2 in. × ·33 = ·660 in. while the space at the bottom 2 in. × ·31 = ·620 in, the angle of thread being 29 degs. No unforeseen circumstances took place in the initial stage of the work, viz.:—roughing out the worm, as it was done in the usual method with a ripping tool manufactured from a bar of 1¼ in. round cast steel. Two tools were required to open out the spaces to the necessary width. It will be noticed that the change wheel *A* has 120 teeth and as it is divisible by 5, the number of threads in the worm, there was no difficulty in having the various threads equally spaced.

Having opened out the spaces to nearly ·620 in., leaving just an allowance to finish, I found that to work out the angle of the thread

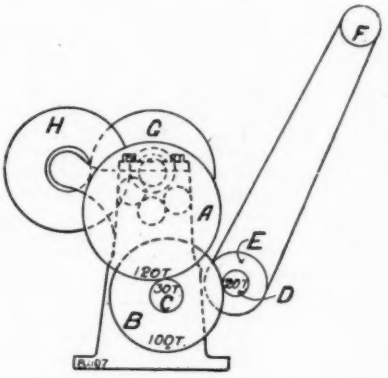


FIG. 1.

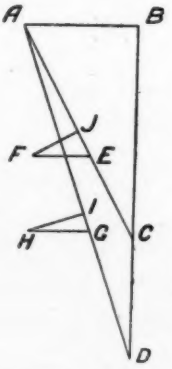


FIG. 2.—CUTTING A 9·25-IN. WORM.

with a forming tool, as is customary in such work, was impracticable as the tool chattered, and, moreover, would make a very unsatisfactory finish owing to the length of lead and to the excessive cutting surface of tool, viz. :— $\frac{\text{Depth of thread}}{\cos 14^\circ 30'} = 1{\cdot}418$ in. My next endeavour was to find a mode of overcoming the difficulty; the only method occurring to me was to angle the slide rest on the lathe and work down the angle of thread with side cutting tools, but it was apparent the angle of the rest must be $14^\circ 30' + \phi$, the normal section of the helix being 29°.

The reasoning employed to find the augmentation of angle of slide rest will be readily grasped by reference to Fig. 2.

Let AB = Lead of worm.
BD = circumference of outside inmeter of worm.
BC = circumference of bottom of worm thread.

Angle $ADB = \alpha$.
Angle $ACB = \beta$.

By drawing EF and GH of equal lengths parallel to AB; and FJ and HI at right angles to AC and AD respectively it is apparent that the difference of HI and FJ would be the error if the slide rest was placed at 14° 30′.

By putting HG or $FJ = a$, and $HI = x$, and $FJ = y$, and as angle GHI is similar to ADB and angle EFJ is similar to ACB,

$$\text{We have } a = \frac{x}{\cos \alpha} = \frac{y}{\cos \beta}$$

$$\therefore \quad y = \frac{x \cos \beta}{\cos \alpha}$$

but $\frac{x - y}{2}$ = perpendicular of angle where base is depth of thread.

By substitution :— $\frac{x}{2}\left(1 - \frac{\cos \beta}{\cos \alpha}\right)$. Hence the tangent of angle sought $= \frac{x}{2\delta}\left(1 - \frac{\cos \beta}{\cos \alpha}\right)$ where δ = depth of thread.

Assuming x = breath of top of thread we arrive at a formula that suits our requirements.

$$\text{Tan } \theta = \frac{\text{pitch} \times {\cdot}33}{2 \times \text{pitch} \times {\cdot}6866}\left(1 - \frac{\cos \beta}{\cos \alpha}\right)$$

$$\text{or } \tan \theta = {\cdot}24c3\left(1 - \frac{\cos \beta}{\cos \alpha}\right).$$

As the angles ADB and ACB with regard to worm under consideration 19° and 26° 5′ respectively; we find angle to be 0° 42′, by adding that amount to 14° 30′ we get 15° 12′ the corrected angle.

Having found the angle the worm was finished in a manner conducive to the interest of the firm of which I am an employee.

N.B.:—I may state that while referring to the slide rest, I am assuming the zero point when it is at right angles to bed of lathe.

J. POLLOCK.

KNOWLEDGE is power, but not necessarily power to earn a comfortable living, as many well educated men can testify.

The British Correspondence School of Electrical Engineering aims at providing, first, a broad general training, and subsequently specialised courses of instruction in the various branches of electrical engineering, the object being to provide just that training which experience dictates is most likely to equip the student for the battle of professional life.

The lessons are prepared, under the supervision of the technical directors of the school, Mr. Frank Broadbent, M.I.E.E., who has extensive practice as a Consulting Engineer, and who is one of the examiners in electrical subjects for the City and Guilds of London Institute, and by Mr. Andrew Stewart, A.M.I.E.E., who is so well known to our readers that any further introduction is unnecessary, though we gather from the prospectus that, being a gold medallist in electrical engineering, and having had not only an extensive experience in electrical engineering in this country, but also in Germany, he is well qualified to deal with the requirements of the students from a broad, one might say, international standpoint.

The courses of instruction are such as will prove of value to those who do not wish to undergo a long training, but who, nevertheless, feel that a working knowledge of modern electrical appliances would prove of value. The address of the school is 36, Maiden Lane, Strand, London, W.C.

RAILWAY NOTES

Self-Propelling Steam Breakdown Cranes.

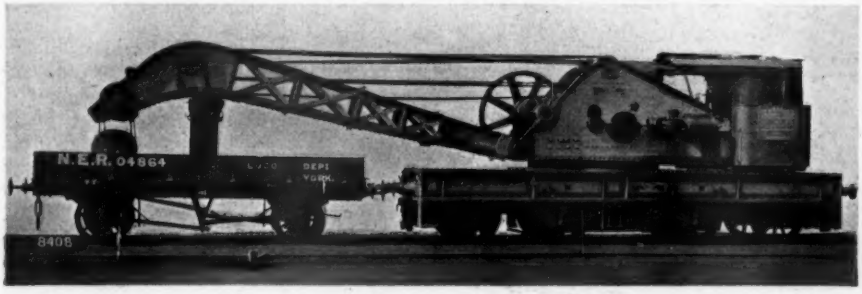
In the accompanying illustration we show a 25-ton self-propelling breakdown crane, one of three recently constructed by Messrs. Craven Brothers, Limited, Manchester, for the North Eastern Railway Company, whilst two similar cranes of 20 tons capacity have recently been made for the Caledonian Railway Company, and one for the Great Central Railway Company.

A salient feature in the design of these cranes is that the axle journals have very large bearing surfaces with efficient lubricating arrangements enabling the crane to run at high speeds to the scene of an accident.

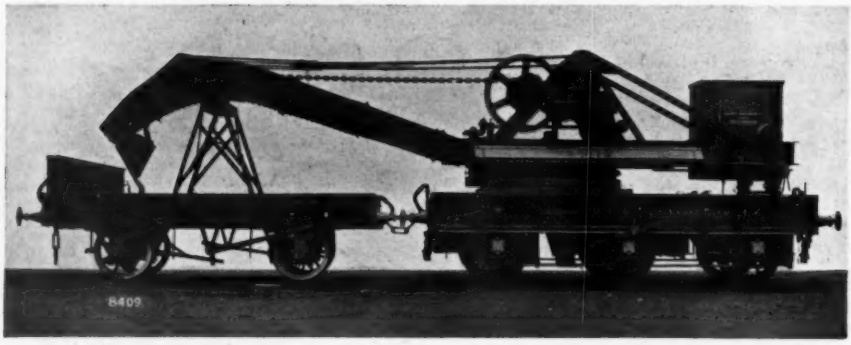
The under-carriage is built of steel plates and girders, braced by cross beams and carries a massive foundation casting fitted with a forged steel centre post of large diameter. The foundation is fitted with a steel roller path and a circular steel spur rack for slewing. The under-carriage is mounted on four pairs of wheels, the two inside pairs carried by horn plates riveted to the frame sides, and the two end pairs each carried by a pony truck having radial movement. This arrangement enables the crane to take the curves of the rail track smoothly and without grinding, and it will run easily in either direction. To the four travelling wheels, brakes are fitted, operated by a hand wheel from the side of the carriage, and a relieving gear is also fitted, so that the weight of the boiler and balance weight may be taken off the centre post when the crane is not working.

The revolving super-structure is constructed on two heavy steel beams, carrying a heavy centre, fitted with rollers, which revolve on the steel path on the under-carriage, and horizontal rollers, which revolve round the centre post.

All the motions of hoisting, slewing, derricking and propelling are worked by a pair of high-pressure reversing engines, carried on the crab sides, one cylinder on each side of the crane, and driving on the crank shaft, from which all the motions are worked. The hoisting gear has two speeds, and the lowering is controlled by a powerful brake on the second motion shaft. The load is carried on two strands of 1¼ in. diameter best quality crane chain, one end of which is securely attached to the grooved chain barrel, then passes over the jib pulley, under the pulley in the lifting block, and is fastened to the shackle at the end of the jib by a hook, which may also be used for two speeds of lifting by single strand of chain for lighter loads. The derricking is worked by a worm gear, the angle of the



25-TON SELF-PROPELLING BREAK-DOWN CRANE.



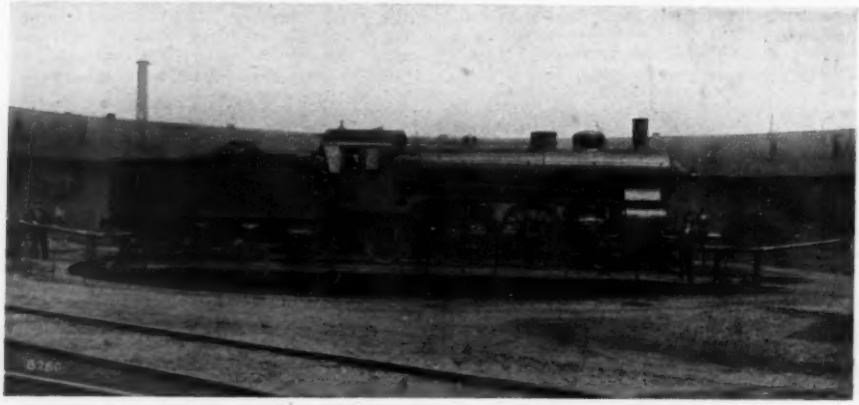
HAND-OPERATED TYPE OF BREAK-DOWN CRANE.

thread of which is self-locking so that it is impossible for the jib to run down. The slewing is worked by bevel and spur gear, driving a pinion gearing into the slewing rack, this motion being fitted with a brake to control the slewing. The self-propelling is worked from the clutch shaft by bevel and spur gear, driving a vertical shaft passing through the centre post and on to the two centre axles. All the gears, axles and shafts are of steel, and the bearings of gun-metal.

There are also included an index and pointer showing the angle of the jib for various loads. Three pairs of draw-out bars to draw out sideways are provided for use when lifting heavy weights, thereby increasing the stability of the whole structure. There are also blocks adjustable to take the load off the springs of all axle boxes when lifting a load. An arrangement for detaching the self-propelling gear when travelling and a set of rail clips to grip the rails when hoisting a load.

The boiler is of the quick steaming type and can get up full steam in about twenty minutes. There is a platform placed between the boiler and the crab, from which the operator can control all the movements of the crane and conveniently attend to the boiler.

The leading dimensions are:—Maximum radius with full load, 21 ft.; height to centre of jib head pulley at 21 ft. radius, 26 ft.; extreme wheel base, 19 ft. 1 in.; fixed wheel base, two inside pairs, 9 ft. 1 in.; cylinders, diameter, 8 in., by 1 ft. 2 in. stroke;



GERMAN ELECTRICALLY OPERATED TURNTABLE.

boiler, diameter, 4 ft. 9 in., height when chimney is lowered, 7 ft.; speed of self-propelling, 4 miles per hour; working load, 20 tons; diameter of driving wheel on tread, 3 ft. 9 in.; total weight with boiler and tanks full of water, but no coal in bunker, 71 tons.

The second illustration is that of a hand-operated type of crane, one of five recently supplied to the Great Central Railway Company.

The under-carriage is built of steel plates and is of similar design generally to the steam breakdown crane previously described, but the foundation casting is arranged with a steel roller path accurately angled, to suit the rollers carried in a live roller ring, instead of centre post and rollers. The live rollers are twenty in number, each revolving on a steel pin carried by the roller ring or spider. This arrangement considerably reduces the friction, and consequently a much freer slewing motion is obtained and wear and tear minimised.

The under-carriage is mounted on three pairs of wheels, and the axle journals have large bearing surfaces, being of the standard tender type of the Great Central Railway Company, and the wheels are so disposed that when the jib is lowered and the crane is travelling along the permanent way in running order, each wheel, as far as possible, takes an equal load, so that the crane may ride easily along the roadway.

The revolving super-structure, crab and jib, are of massive design, and a balance box is provided running on four runners and adjustable by screws at the tail of structure. A relieving gear is fitted on the carriage to come up under the tail end of the revolving structure, so that when the crane is not working and in running order, the weight of the balance weight may be taken off the revolving structure and lock it in position.

The jib is of strong riveted construction, the tie rods being jointed telescopically and fitted with cotters which can be readily withdrawn when it is desired to lower the jib, and placed in a second set of cotter holes lower down the tie rods to hold the jib in position. The jib is lowered by hoisting the lifting block up to the point of jib and easing the weight off the cotters and then lowering gradually by the handles. The lifting and lowering motion is worked by means of a grooved barrel, to take the full length of chain without overlapping, and treble-purchase spur gearing. An $1\frac{1}{8}$ in. short link chain is attached to the barrel and passes over the guide pulley, the pulley at point of jib, and under the pulley in the lifting block, and is fastened to a shackle at the point of jib by a swivel hook attached to end of chain. When desired light loads can be handled quickly by unhooking the chain from the shackle, removing the main block and using single strand chain only.

The slewing and hoisting are actuated from separate shafts, and a powerful foot brake is provided to control the slewing motion. The hoisting gear has three changes of speed and construction, such that in the hoisting direction the pawls run free of the ratchet teeth, but in the lowering direction the pawls engage in the teeth and hold the load until the brake strap is released by the brake lever.

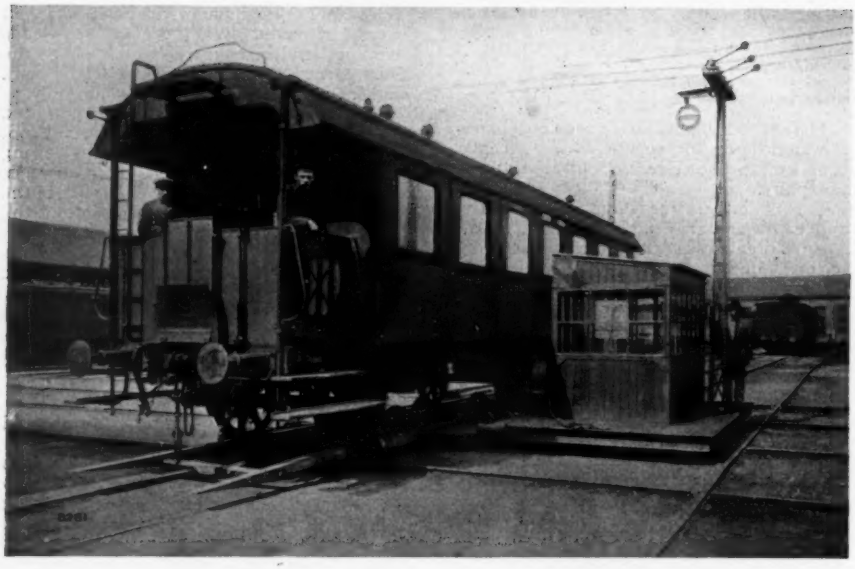
Modern German Electric Turntables and Transporters.

The illustration opposite shows the old type of turntable of German design for shifting locomotives and carriages into engine houses and sheds, electrically equipped, the electric motor taking the place of the old style hand power, and doing the work with greater economy in cost of operation as well as with a great saving of time. The operator simply stands at the controller wheel at one end of the locomotive turntable platform, from which location he can handle the device without effort, the electric motor running on a circular track in the turntable pit with rack and pinion, turning the locomotive to the track desired.

The illustration on p. 416 shows another electric transporter or transfer table of German design constructed by the Vereinigte Maschinenfabrik Augsburg und Maschinenbau-Gesellschaft, Nurnberg, on which three-phase alternating current motors are used, the current being taken from three overhead wires by three short trolley poles. The cars are run on to a platform about 30 mm. above the regular tracks and having a total length of 15 meters. It is provided with rails of Siemens-Martin steel and the ball-bearing rollers or wheels operated in four rails running across the yard.

The motor is located in the building on the platform and is geared to the driving wheels, the gearing running in oil. The brakes are so controlled that the motor starting device cannot be moved until the brakes are released, and the brakes cannot be set without automatically shutting off the current.

An electrically operated winch or capstan is provided with a reel of steel cable as



GERMAN ELECTRICALLY OPERATED TRANSFER TABLE.

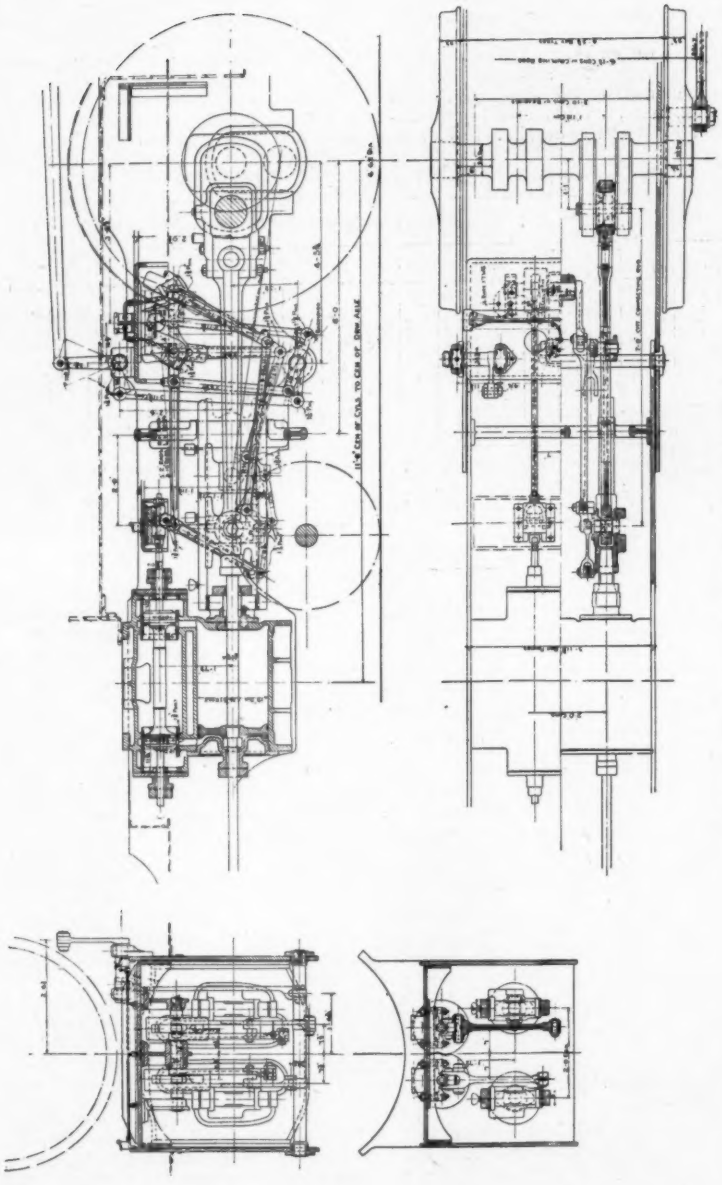
shown in the illustration, electric power being employed for hauling the cars on to the transfer table if so desired.

New Valve Gear on a Midland Passenger Engine.

In accordance with our promise made in the October number we are now in a position to give fuller particulars, accompanied by illustrations, of the new valve gear with which Mr. R. M. Duley, locomotive superintendent of the Midland Railway, has fitted No. 999, the latest type of express passenger engine put into service by him. It will be seen that the use of eccentrics has been dispensed with, although the valve movement and consequent distribution of steam is similar to that of the "Stephenson" gear with the single exception of the lead. The design of the gear is such that the left-hand expansion link is in advance of the right-hand one, the reversing shaft being placed between them with one arm forward and the other backward. This permits of the die on one side being at the top of its expansion link and the other at the bottom, and also effects a balance of these parts. Further, the oscillatory movements are transferred from one side of the engine to the other, which would be a matter of some difficulty were both links situated on the same transverse axis.

The expansion links, it will be observed, are not symmetrical with respect to the trunnion on which they oscillate, nor are the reversing arms truly horizontal in the position of mid-gear. These positions, however, have been called for in the design of the gear, and being placed as they are, compensate for the varying angularity of the connecting rods and so ensure a uniform steam distribution. The latter, as will be observed from the accompanying tables, is of a very high order.

The resemblance of the design to that of the "Walschaert" gear will be noticeable in connection with the means adopted to give the lap and lead movement to the valve. This is effected by a pendulum link operated by a rod from the crosshead. The expansion link is also operated by means of a link attached to the crosshead on the opposite side of the engine instead of being actuated directly by an eccentric on the crankshaft. This will best be followed in the plan of the gear. Thus the two sides of the engine are not independent as in the case of ordinary link gear, which, however,



NEW VALVE GEAR OF MIDLAND EXPRESS PASSENGER ENGINE, NO. 999.

cannot be ranked as an objection in view of failure of the gear on one side disabling the whole engine, as that latter contingency is highly remote considering the high-class material and workmanship that obtains in modern practice. In addition to the advantage gained by the simple nature of the moving parts, another and highly important one is that the crank axle can be

R.H. SIDE.

	Notch.		Travel.	Lead.			Port opening.			Cut-off, per cent.			Release, p.c.			Angle of release.			Compress'n, p.c.		
	No.	Angle		F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.
			Ins.																		
Forward	12	—	4 1/16	1/16	1/16	—	1/8 + 1/16	1	1/16	69	65·5	3·5	90·2	87	3·2	51	50·5	·5	87	90·2	3·2
	9	—	3 13/16	,,	,,	—	1/8 b	1/16 f	1/16 f	57·3	54	3·3	86	82·5	3·5	43	43·5	·5	82·5	86	3·5
	6	—	3 9/16 f	,,	,,	—	1/8 f	1/16 b	1/16 b	39·5	38	1·5	79	75	4	31·5	33·5	2	75	79	4
	3	—	2 5/16 b	,,	,,	—	1/4 b	1/4 b	—	20·2	18·7	1·5	67·5	64	3·5	16·5	20.5	4	64	67·5	3·5
	Mid	18°	2 1/16	,,	,,	—	1/16	1/16	—	8·7	6·5	2·2	52·5	49·5	3	89	93	4	49·5	52·5	3
Backward	3	—	2 5/16 b	,,	,,	—	1/4	1/4 b	b	20	17·2	2·8	66·5	62·5	4	75	71·3	3·7	62·5	66·5	4
	6	—	3 1/16	,,	,,	—	1/8	1/8	—	38·5	36·5	2	78·5	74·5	4	59	57	2	74	78·5	4
	9	—	3 13/16 f	,,	,,	—	1/8 f	1/8	1/16 b	56	53	3	85·2	82·2	3	48	46.5	1·5	82·2	85·2	3
	12	37·75	4 1/16 b	,,	,,	—	1/16 b	1/8	1/16 f	68·5	64·5	4	90	87	3	40	39	1	87	90	3

Outside lap of valve, 1 1/8 in. Clearance of die, top, 1/8 in. b; bottom, 1/16 in. Slip of die, top, 1/16 in. f; bottom, 1/16 in.

L.H. SIDE.

	Notch.		Travel.	Lead.			Port opening.			Cut-off, per cent.			Release, p.c.			Angle of release.			Compress'n, p.c.		
	No.	Angle		F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.	F.	B.	Diff.
			Ins.																		
Forward	12	—	4 1/16 b	1/16	1/16	—	1/16 b	1 b	1/16	69	65·5	3·5	90	87·3	2·7	50·2	51·2	1	87·3	90	2·7
	9	—	3 13/16	,,	,,	—	1/8	1/16	1/16	55·5	52·5	3	85·5	82	3·5	42	43	1	82	85·5	3·5
	6	—	3 9/16	,,	,,	—	1/16 b	1/16 b	—	37·7	35·5	2·2	78	74	4	30·2	32·5	2·3	74	78	4
	3	—	2 5/16	,,	,,	—	1/4	1/4	—	20	17	3	65·8	61·5	4·3	14·2	17·7	3·5	61·5	65·8	4·3
	Mid	18°	2 1/16	,,	,,	—	1/16	1/16	—	8·5	6·3	2·2	50·5	47	3·5	86·5	91	4·5	47	50·5	3·5
Backward	3	—	2 5/16	,,	,,	—	1/4	1/4	—	22·3	20	2·3	69	65	4	71·5	68	3·5	65	69	4
	6	—	3 1/16 f	,,	,,	—	1/16 f	1/16 b	1/16	42·3	40·2	2·1	79·8	76·4	3·4	57	54·2	2·8	76·4	79·8	3·4
	9	—	3 13/16 f	,,	,,	—	1/16	1/16 f	1/16 f	58·7	56	2·7	86	83	3	46·9	45°	1·4	83	86	3
	12	37·75	4 1/16	,,	,,	—	1/16 b	1 b	1/16	69	65·7	3·3	90	87·2	2·8	39·7	39	·7	87·2	90	2·8

Outside lap of valve, 1 1/8 in. Clearance of die, top, 1/16 in.; bottom, 3/8 in., b. Slip of die, top, 3/8 in., b; bottom, 1/16 in.

made of stronger dimensions and larger areas given to the bearing surfaces. Another well thought-out detail is that the small ends of the connecting rods are fitted with ball and socket joints, permitting oscillations of the engine on the driving wheels without setting up any strain on the motion which would otherwise arise since the slide blocks are made a good fit to ensure steady running.

The Locomotive of the Future.

In all probability at some distant date the steam locomotive will be discarded for one driven by electricity, or some other power as yet unthought of. However, such an enormous amount of money would have to be expended in making the change that the locomotive will unquestionably be used for a long time yet, and the change when it does come will be a very gradual one. Doubtless some form of water-tube boiler will eventually supersede the present form of boiler. This, if satisfactorily designed, should not only prove equally light and economical, but a far more rapid steam generator in time of stress. On the Austrian State Railways, fifteen engines are now running fitted with the type of water-tube boiler designed in 1901 by Herr Brotan, and with such satisfactory results that nineteen more engines are to be built with this type of boiler.

It is an exceedingly doubtful question if the future British express engine will be a compound. From statistics that have lately been taken with great care a compound express engine appears to save three farthings a mile, or less than a third-class passenger's fare. It is, however, a well-known fact that compound engines cannot compete with "simple" in regard to speed and ease of starting, unless fitted with complicated starting arrangements. If,

therefore, on two competitive lines, one railway succeeds in attracting one more passenger by a better train service, that railway will have more than covered the extra expenditure involved by the "simple" engine.

Many people wonder why the French "de Glehn" compounds were not such a success, when introduced on the Great Western Railway, as they were in their native country. The reason is not very difficult to discover. Take, for example, the Northern Railway of France. As this railway pays a dividend of about 15 per cent. M. de Bousquet, the locomotive superintendent, has not to consider his coal bill. The result is that the drivers have orders to get the trains through to time at all costs. According to Mr. Alister Mackinnon, who recently expressed his views on the subject of modern locomotive practice before a graduates' meeting of the Institution of Mechanical Engineers, these express engines (which are mostly built on the "de Glehn" compound system), during their run from Paris to Calais, are worked about one-third of the time as "simple" engines. It is thus not to be wondered at that they are able to combine great speed and hauling capacity. In this country, however, the commercial side of the matter plays a very important part, and the pecuniary question is the real reason why the "de Glehns" were not nearly so successful when introduced over here, as in England we are compelled to consider the coal bill.

Turbine locomotives have lately been experimented with in Germany, but up to date have not met with much success. It is quite impossible to say at present if they will finally be of any commercial value.

Probably the future locomotive will use high-pressure steam, probably even higher than the highest we have yet reached. Superheating will also be most likely resorted to (especially if fuel be expensive), and some form of a condenser may be fitted to engines in order to reduce the back pressure.

New Electrical Fog-Signalling System on the South Eastern and Chatham Railway.

The ushering in of the season of fogs by the disaster on the Metropolitan Railway at West Hampstead naturally sets one's thoughts in the direction of the numerous systems that have been invented and tested with more or less success, for an adequate system of signalling under such conditions, and the replacement of the older method of employing detonators. The experimental lengths equipped by the Great Western Railway at Fairford, and of the Great Central at Woodhead Tunnel, were thought at the time to hold out much promise, but nothing further has been heard of them as being likely to become extensively adopted. The latest company to adopt a practical test of an auxiliary signalling system is the South Eastern and Chatham who, for the past nine months, have been experimenting with a new system at Penge Junction signal box, on a short length of line between Beckenham Junction and Norwood. The apparatus, which is the invention of Messrs. Smith and Bounvialle, is electrically operated, and indicates in the signal box itself and on the engine, the position of both home and distant signals, or, what is better still, the positions of the levers operating these, so that the conditions as existed at the time of the catastrophe at Arbroath, when the semaphores dropped from the weight of snow on them, would not mislead the driver, since the tell-tale semaphore in the cab would indicate the true state of affairs. The signals conveyed to the driver are of two kinds—audible and visual. The first is by means of a bell which rings on entering and leaving a section of rail adjacent to the distant and home signals; the second of miniature semaphores, and also green and red lamps, corresponding to the position of the actual home or distant signals. Lamps in the signal box correspond with those on the engine, and are lighted up and extinguished at the same time. A telephone is also provided so that driver and signalman can communicate should it be necessary when a train is stopped at a signal. The apparatus whereby this is effected is simple. On a length of line, about 50 yards in length, adjacent to both home and distant signals, a pair of contact rails are provided between the running rails, one or other of the former being energised by a battery of sixteen Leclanché cells, according to the position of the signal lever in the cabin. Fitted on the locomotive is a pair of shoes which make contact with the rails as they pass over them, thus completing one of two circuits according to which contact rail is energised. For example, assuming that the distant signal is in the caution position, the left-hand contact rail is energised, and the right-hand one is dead. The shoe on locomotive on making contact completes the circuit, the red lamp will light up, and the tell-tale semaphore

remains unmoved, but a small pointed flag makes its appearance as a caution to the driver. On leaving the contact rail length, the red light will be extinguished, but the warning flag will continue to remain in view in the frame. In the opposite case, that is, when the distant signal is at "clear," the miniature semaphore will drop and the corresponding green lamp light up. In both cases the green or red lamp over the lever and in the signal box, by which the distant signal is actuated, is lighted up and extinguished in the same manner. Following now the train to the home signal, which we will first suppose is at the "caution" position. Circuit is completed in the same manner, the red lamp will light up, and the driver will bring his train to a standstill. He will be advised to proceed by the tell-tale arm dropping, the disappearance of warning flag, and the green lamp lighting up. Should both lamps go out, it is an indication that the signalman has taken down his telephone and wishes to speak to the driver. In the event of the home signal being "clear," the flag will disappear and the green lamp light up. So much for the electrical and visual side of the system. In addition, the driver's attention is called to the approach of a train to a signal, and the passing thereof, by the sounding of a bell, which, however, is operated mechanically by a "Bowden" wire connected with the contact shoes. The latter are pressed upward by the camber of the contact rail, thus actuating the bell trigger. The taper at the other end of the ramp allows the contact shoes to return to the normal position, whereby the trigger and bell are actuated again. An electric bell in the signal cabin is also sounded at the same time, intimating to the signalman that the train has reached the point in question. The driver can either stop his train at the first ring when approaching the home signal or slow down and stop on getting the second ring. He thus knows exactly *where* to stop—a very important point, and one greatly in favour of the system. During the period in which it has been under trial, the apparatus is said to have operated satisfactorily, and at a recent Board of Trade inspection favourable opinions, we understand, were expressed.

Mr. Whale and the Shrewsbury Disaster.

In view of the wide interest that the disaster at Shrewsbury has aroused and the numerous theories that have been advanced as to the probable cause, the following letter written to the *Railway Magazine* is worthy of reproduction. Mr. G. Whale, the Chief Mechanical Engineer of the London and North-Western Railway, who is also the designer of the engine, throws considerable light on the special construction of this locomotive, and also gives an authoritative opinion on some of the theories. He states:

"There was no failure in the steam regulator, or any of its connections, and, even if there had been such a failure, the regulator is so constructed that the valve would have closed automatically and cut off the steam supply to the cylinders.

"No case has ever come under my notice where the cylinder ends have been carried away in consequence of reversing the engine when in steam. It is possible, but not probable, that the gear may be reversed with steam on in some engines and not in others; it depends entirely upon the nature and design of the reversing gear, but I should think it very unlikely that any engine of good design would be fitted with gear which could not be reversed under steam."

MANUFACTURERS' NOTES.

Lancaster & Tonge, Ltd., Pendleton, notify us that they have supplied their "Lancaster" steam traps for draining the steam ranges, &c., in the Cunard S.Ss. *Lusitania* and *Mauretania*. **The Kennicott Water Softener Co.,** Great St. Helens, E.C., advise that they have recently secured the undermentioned orders for their water softening apparatus:—Steel, Peech & Tozer, Ltd., Sheffield, 30,000 galls. per hr., type "A"; Brodsworth Main Colliery Co., Ltd., 15,000 galls. per hr., type "A"; Naval Colliery Co., Ltd., South Wales, 4,500 galls. per hr., type "B"; James Oakes & Co., Alfreton, 3,000 galls. per hr., type "B"; The Doncaster Wire Co., 2,000 galls. per hr., type "B"; John Fleming & Co., Kilmarnock, 500 galls. per hr., type "B"; South India Railway, 2,000 galls. per hr., type "A." **Applebys, Ltd.,** and **The Temperley Transporter Co.** announce that the interests of their respective firms have been amalgamated, and that they have taken the title of **Applebys, Ltd.,** with offices at 58, Victoria Street, Westminster, and works at Glasgow and Leicester. Mr. John R. Temperley and Mr. Joseph Temperley, hitherto sole partners in the Temperley Transporter Co., have joined the board of directors of Applebys, Ltd., and will continue in the active management of the business. **Walter P. Notcutt,** 8, White Street, E.C., notifies that he has been appointed British representative for the Smooth-on Manufacturing Co., Jersey City, U.S.A., manufacturers of "Smooth-on" iron cements, &c. **Princeps & Co.,** Sheffield, advise us that they have appointed E. B. Clarke, of Norfolk Street, Sheffield, as their sole agent in South Yorkshire, Nottingham, and Derby, and Messrs. E. Bowden & Co., of Merchants' Exchange, Bute Docks, Cardiff, as agent for South Wales.

GENERAL REVIEW

LEADING ARTICLES OF THE MONTH—CURRENT EVENTS—TECHNICAL INFORMATION FROM ALL SOURCES.

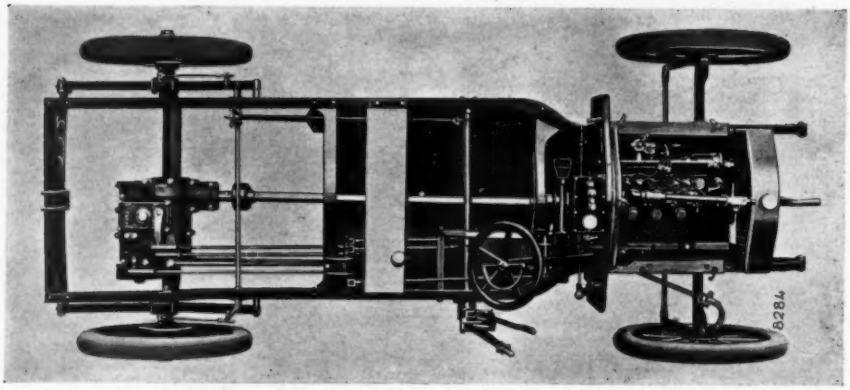
The Extension, Widening, and Strengthening of Folkestone Pier.

At a recent meeting of the Institution of Civil Engineers a paper was read on this subject by Mr. H. T. Ker, member, who acted as resident engineer during the construction. The communication describes the important harbour-works which were carried out by the South-Eastern Railway Company, at Folkestone, during the eight years from 1897 to 1905. The paper begins with a short historical account of the early works carried out for the purpose of providing shelter, and of the continuous fight against the travelling shingle which tended to block the harbour entrance. The accumulation of shingle against these earlier works has resulted in high-water mark being pushed about 900 feet seaward, and the reclamation of about 26 acres from the sea.

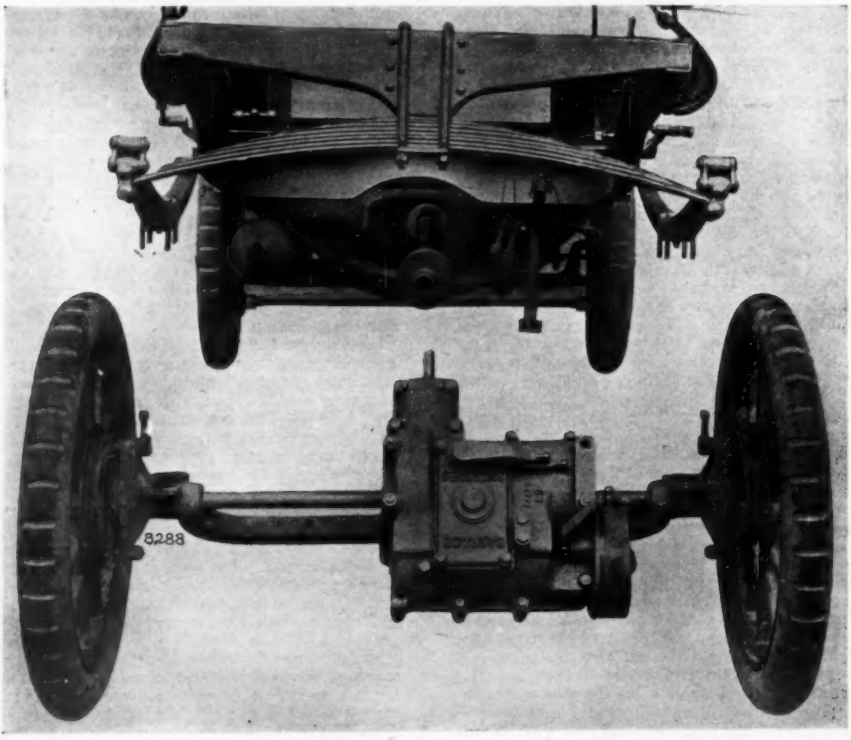
The old pier, in 1897, was in a very dilapidated condition, and ill adapted for the rapidly increasing traffic. The number of passengers by the Folkestone-Boulogne route in the year 1905 was 257,000, and the value of the goods dealt with was £12,500,000. The new works, designed to meet the increased traffic requirements comprise: the extension of the old pier by 900 ft. of solid work, with the provision of four new berths available at all tides and in all weather; the protection of the west face of the old pier by a solid wall carried down to a secure foundation; the strengthening of the root of the pier by a wall founded on cylinders and protected by a wave-breaker of 20-ton blocks deposited pell-mell; the renewal of the east face of the old pier in greenheart piling, and the provision of a new deck throughout its length. The pier is provided with a sheltering parapet along the whole of the western side. The parapet covers the railway platforms, and provides a public promenade on the top. The main lines and sidings on the pier are controlled by electric signalling, and the whole of the pier, landings, and station-buildings are lighted by electricity. The pier terminates in a round-head 65 ft. in diameter, upon which stands a granite light-house, exhibiting a fourth-order double-flashing light; and a fog-horn house with air-compressing machinery.

The paper proceeds to describe the construction of the new works, and gives details of the extension, which was composed of 20-ton concrete blocks, of which 133,500 cubic yards were used in the works. Reference is made to the methods adopted for testing cement, and particulars are given of the boiling test used as a measure of the aëration necessary. Experiments were made with 100-ton lots to ascertain the increase of volume due to aëration, and particulars are given of one of the consignments tested in this manner which continued to increase at a rate sufficient to pay the cost of turning the cement up to the twenty-second turn. Tests extending to three years were also made of cement which had been adulterated with gypsum to control its setting properties, and the results are given, showing a serious diminution of strength in the last year of the test with neat cement, but a steady increase with the mortar test.

After a description of the block-making and stacking, mention is made of the staging from which the actual building was carried on. This staging was 101 ft. wide and 400 ft. long, with its rail-level 21 ft. above high water. It was formed of Oregon pine piles, 18 in. by 18 in., carrying lattice girders of 40 ft. span. The staging carried two 30-ton and two 20-ton goliath cranes. The 30-ton goliaths were used for handling the diving-bells, of which there were two, each 13 ft. by 10 ft. by 6 ft., weighing 26 tons. The 20-ton goliaths were used mainly for block-setting. The blocks below low water were set block to block, without beds, by the divers. Above low water the blocks were set in beds of 2-to-1 mortar, and the joints were grouted. At the outer end of the pier the foundation was 63 ft. below high water. The whole of the west side of the pier is protected against undermining by a concrete apron 13 ft. wide. Above low water the pier is faced with granite which was built into the blocks in the yard. Grooves are formed in the granite where the landings occur, to receive the



CHASSIS OF THE FOUR CYLINDER 18 H.-P. DARRACQ CAR, SHOWING THE GEAR BOX AND DIFFERENTIAL IN ONE UNIT.

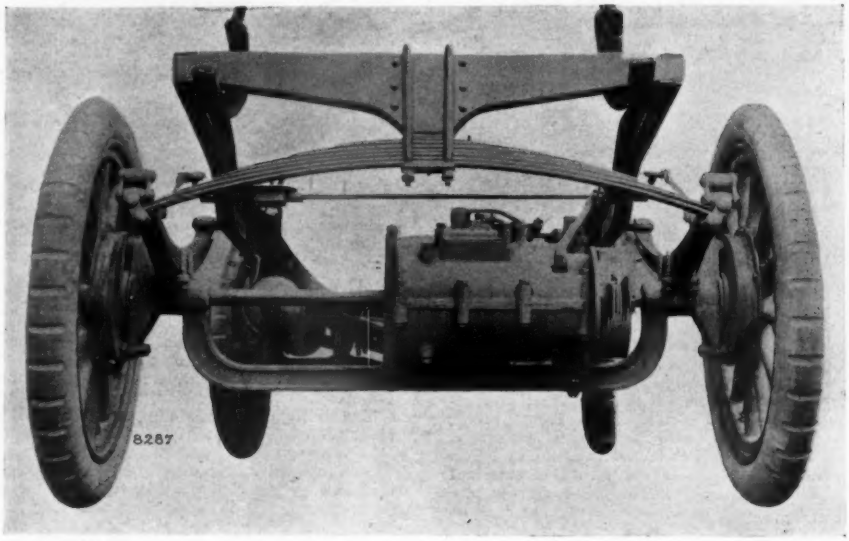


THE BACK VIEW OF THE NEW DARRACQ CHASSIS, WITH THE BACK AXLE GEAR BOX AND DIFFERENTIAL REMOVED EN BLOC.

greenheart piles which carry the decks of the landings. Each berth is provided with a lower landing, 20 ft. wide, so that passengers may embark with convenience at any state of the tide. Slipways are also provided for the shipment of horses, of which traffic there is a considerable amount passing through Folkestone.

The paper next describes the strengthening works at the root of the pier where, owing to the proximity of the old work and the amount of cover to be removed before obtaining a good foundation, it was necessary to resort to cylinders to obtain a secure footing in the lower greensand beds. The site of the cylinder foundation was in a re-entering angle exposed to a heavy wave-stroke. The cylinders, which were 11 ft. in diameter, were in two rows. Those in the front row were built up of steel rings 5 ft. deep, while in the back row the cylinders were made of concrete in sections, each weighing nearly 20 tons. The steel cylinders were sunk by means of compressed air, and the concrete cylinders by grabbing in the usual way. The obstructions met with during the process of sinking consisted of the débris of the old pier in the shape of rocks, concrete, and old rails which had to be cut through. The blockwork wall built on the top of the cylinders was backed with chalk filling upon which the main pier-station was built. The cylinder-wall was protected from the abnormal wave-stroke at this point by a wave-breaker composed of 460 blocks, each weighing 20 tons, placed as irregularly as possible.

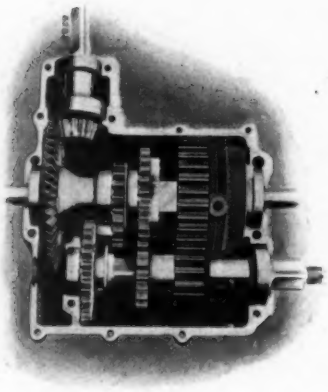
The main passenger-lines running on to the pier had been liable to damage during stormy weather owing to the loss of shingle which occurred during gales. Foreshore-protection works of a permanent character were therefore constructed, consisting of groynes, breast-walls and rockwork barriers. The paper concludes with a description of the greenheart face and new landings provided on the east face, and with a notice of the special cranes provided for the rapid handling of baggage.



REAR VIEW OF THE DARRACQ CHASSIS, SHOWING THE H SECTION BACK AXLE, GEAR AND DIFFERENTIAL BOX.

The 18 h.p. Darracq Motor Car—The Elimination of the Gear Box.

The 1907 automobile exhibition at Olympia, although as far as can be ascertained was as successful as any of its predecessors, was marked by no remarkable improvements or changes in design—with one exception, and that was in the 18 h.p. vehicle exhibited by A. Darracq & Co., Ltd. The most striking feature of the new car is the transmission, the change-speed gear elements, differential, and bevel gearing being contained in one casting disposed on a solid rear axle with independent parallel driving shafts. One long cardan shaft connects the drive from the clutch to these driving shafts, thus the machine consists of two parts only—the motor and the differential



DARRACQ GEAR BOX AND DIFFERENTIAL IN ONE UNIT; COVER REMOVED TO SHOW SIMPLICITY OF CONSTRUCTION.

—and the usual intermediate gear box is eliminated.

The combination of the gear box and differential in one unit is a decided innovation, although it has been known for some time that M. Darracq has been working in this direction. In fact, it has been exhaustively tried on all the recent Darracq racing cars, and so efficient has it proved that it is now being fitted to the standard touring car of 1908. It is a step in the direction of the total elimination of the gear box, and brings with it a reduction of working parts and a considerably increased accessibility. The simplicity of this combination will be apparent when it is stated that the box containing the change speed gears and differential can be removed merely by unscrewing four bolts.

In the new model the rear axle and change-speed gear form practically one unit. The axle proper which carries the road wheels is solid for the best part of its length, and is of H section forged nickel steel. This solid section is deeply bowed, the ends assuming a horizontal position, and bored through to accommodate the driving shafts. The gear-box containing the change-speed gears, differential, driving bevels, &c., is of oblong shape, and is bolted in a transverse position on the top of the solid axle. This latter being deeply bowed, as previously mentioned, brings the horizontal ends in a line with the differential driving shafts on either side of the gear-box. These driving shafts pass through the bored ends of the solid axle, and drive the road wheels through the medium of a dog clutch. The space between the flywheel of the engine and the axle is practically bare, only the long cardan shaft and the brake and change-speed connecting rods occupying that space. The construction of the change-speed gear elements

THE HUB CAP OF A DARRACQ REAR WHEEL REMOVED TO SHOW THE METHOD OF COUPLING THE DRIVING SHAFT TO THE HUB.

needs explanation. Assuming the detachable top of the gear-box is off and we are looking down on the mechanism, two points strike one as being different from the orthodox practice, *i.e.*, the large bevel wheel on one end of the primary shaft and the differential gear at the other end.

The sliding elements are fitted to the primary shaft with a dog clutch for the direct drive. Ball bearings are fitted to all parts. Three speeds forward and one reverse are provided, operated by the side hand-lever, which has a gate control. It is worthy of note that the ends of the long coupling rods connecting the change-speed lever to the arms carrying the forks for the collar of the sliding wheels are fitted with ball and socket joints, as are also the brake coupling rods.

The front axle is of H-section steel, with steering coupling rod behind, ball and socket joints from pivot to worm gear arm, and a universal joint at the front end. Large ball bearings are being fitted to the rear end of the connecting rod fitted to the road wheels.

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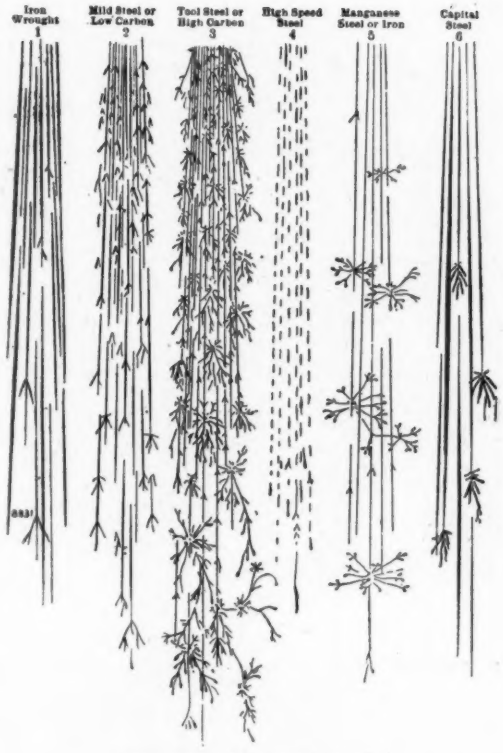
A Spark Method for Grading Steel.

A method of grading steel depending on the action of oxygen on the more combustible elements contained in the steel which tend to act explosively when a certain temperature has been reached, is described by a writer in the *American Machinist*. By the

action of grinding or by projecting filings through the flame of a candle, sufficient heat is imparted to set up chemical action between the oxygen of the air and the iron, the resulting combustion being of sufficient intensity to ignite the carbon contained in iron or steel. If a bar of iron be heated to a welding heat and then held in a strong air blast it will begin to boil and splutter, a bluish-white light being emitted. Adopting this means for the test, wrought iron will be found to give broad straight lines—see (1) of the accompanying figure—which increase in luminosity and then disappear. The addition of carbon is noticeable by a division or forking of the luminous streaks as in (2). With the increase of carbon the iron lines, however, become less conspicuous, but divide and sub-divide as in (3).

The peculiarities exhibited by (4) and (6) are that the sparks are a very dull red and simple in character. The characteristic manganese spark is shown at (5) and will be seen to differ widely from the carbon stars and rays. Once these diversified signs have been carefully studied, the trained eye will detect the slightest trace of manganese in even what is otherwise a pure carbon steel. Its spark is shown in 5. The lateral darts always radiate from an unbroken line and at right angles thereto. The colour is dull red and each dart is subdivided into anumber of white-hot globules.

Some steelmakers use the method of spark analysis in testing their products, in addition to others, and they agree that it is very reliable. In addition to the diversified sparks shown in the diagram, there is also much significance in the distance in which they appear from the source of heat as in grinding, which is the most accurate test.


Iron Wrought 1
Mild Steel or Low Carbon 2
Tool Steel or High Carbon 3
High Speed Steel 4
Manganese Steel or Iron 5
Capital Steel 6

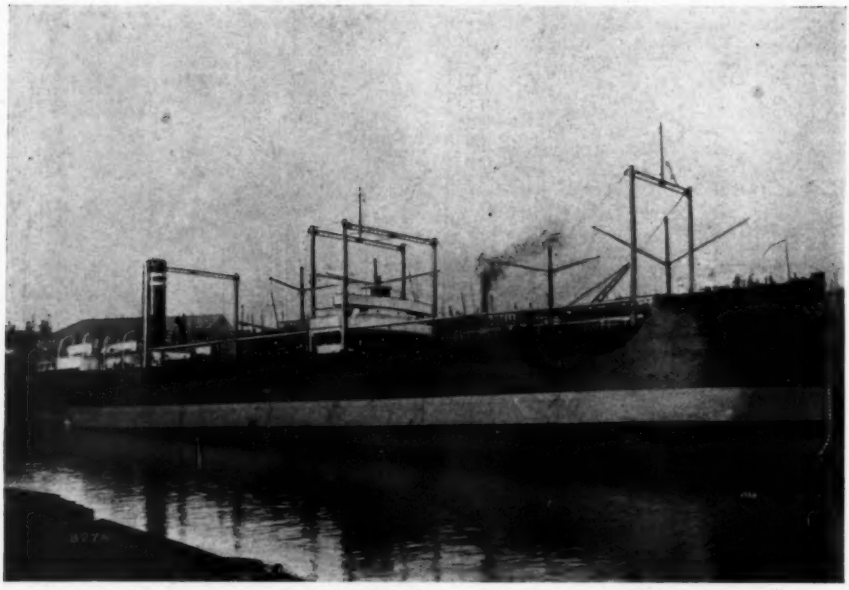
SPARK METHOD FOR GRADING STEEL.

A New Trunk Steamer.

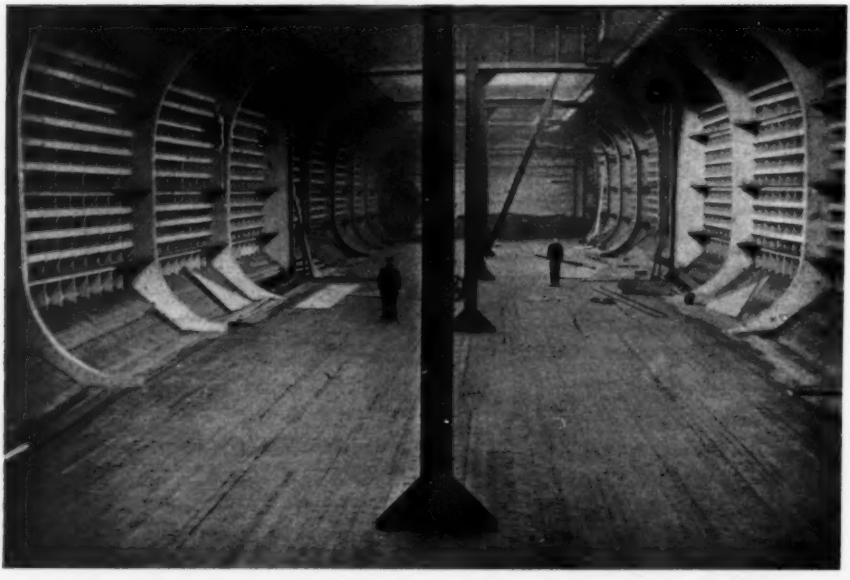
A finely modelled screw steamer built to Norwegian account, by Messrs. Ropner & Sons, Ltd., of Stockton-on-Tees, forms the subject of the half-tones illustrated on page 426. She is a large trunk vessel, with one clear hold and the engines placed aft. She is built to British Corporation highest class and Norwegian law. The steamer is designed for the ocean coal carrying trade, although she is equally well adapted for deadweight or bulk cargoes. The tendency of the age is to build vessels with the largest possible clear holds and hatches; this vessel has one hold only, 256 ft. in length, and two hatches each 102 ft. long and 28 ft. wide. Her dimensions are: 372 ft. by 52 ft. 6in. by 25 ft., and she will carry 7,550 tons deadweight loaded to her summer load line, and has a capacity of about 10,000 tons measurement.

The captain and officers are housed in the poop, and the engineers in houses built on the poop. There is a charthouse and navigating bridge built on a narrow platform spanning the hold amidships.

She has over 2,000 tons of water ballast, 470 tons of which is situated above the main deck in the trunk ballast tanks well above the centre of gravity of the vessel, thus ensuring a steady ship, and a good draft in ballast trim. These tanks and the permanent bunkers are coated



TRUNK STEAMER FOR THE OCEAN COAL CARRYING TRADE.



THE STEAMER HAS BUT ONE CLEAR HOLD AS SHOWN, THE ENGINES BEING PLACED AFT.

with Wailes, Dove & Co.'s bitumastic enamel. She is a self-trimmer, and only such portable centre line pillars are fitted as will be necessary to secure the shifting boards when these are required. There are no quarter line pillars. She is fitted with eight large derrick masts and eight derricks, with nine steam winches by Messrs. R. Roger & Co., Ltd., of Stockton-on-Tees, to allow of expeditious loading and unloading of cargoes.

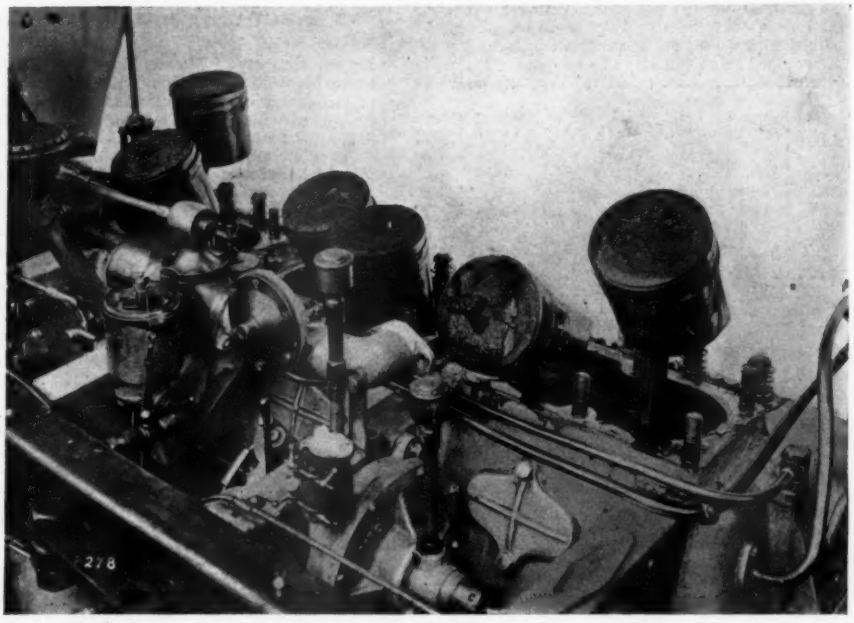
She is fitted with electric light and also with fire-extinguishing appliances to the hold. The ballast pumps, of which there are two, one by Messrs. Blair & Co., Ltd., of Stockton-on-Tees, and the other a duplex pump by Messrs. Henry Watson & Sons, of Newcastle-on-Tyne, are capable of dealing with about 2,000 tons of water ballast in six hours, when pumping the tanks up, or pumping out.

The engines are by Messrs. Blair & Co., Ltd., 26 in., 42½ in., 69½ in. by 45 in., and two boilers, 16 ft. 9 in. by 11 ft. 6 in., working at 180 lbs. pressure. She has also a large multitubular donkey boiler, 11 ft. by 10 ft., working at 100 lbs. pressure. She has an evaporator, feed-heater, and "Crompton" atmospheric ash hoist.

A 3,000 Miles Benzol Trial on a "Napier" Car.

In view of the proposal to adopt benzol fuel as a substitute for petrol in the propulsion of motor cars,* the accompanying illustration of the engine of the 40 h.p. six-cylinder "Napier" car, after it had completed its 3,000 miles test on Simcar benzol fuel, under the auspices of the Royal Automobile Club, will prove of interest.

The amount of carbon deposit on the top of the pistons on the completion of the run is very clearly shown. It will be noticed that it is not excessive, though probably a little greater than would have been the case had a lighter spirit been used. No doubt is expressed, however, that it was caused chiefly by impurities in the benzol, as that used was not in and way specially refined or prepared for the purpose; but was just as it is normally produced as a by-product in the manufacture of other substances. There can be no question that, if this spirit were specially prepared for motor car use, as is petrol, greatly improved results would be



ENGINE OF THE "NAPIER" CAR DISMANTLED TO SHOW THE CARBON DEPOSIT ON PISTONS, AFTER RUNNING 3,000 MILES ON BENZOL.

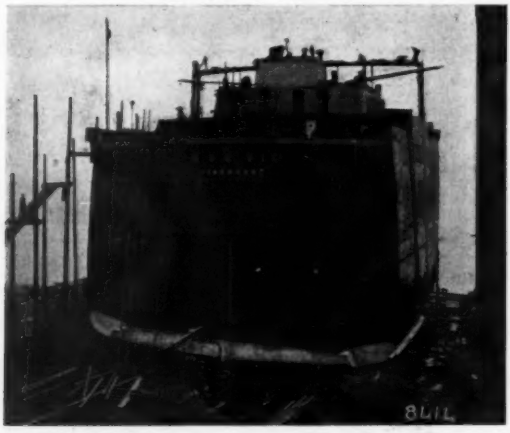
* Cf. THE ENGINEERING REVIEW, p. 201.

obtained. In a measure, however, it may be said that the test has been more satisfactory owing to the impurity of the benzol used than had a purer spirit been employed, since it points to the fact that a British by-product produced by a large number of firms all over the country is obviously capable of running a motor car efficiently, and is one, moreover, that could not possibly be cornered by a clique of financial manipulators. As to the character of the deposit and the action of the fuel on the engine, many were of opinion that deleterious action would be set up, especially on the valves. This apparently is not the case. No difference can be detected in the cylinders, pistons, valve seatings, valve guides, valves, valve stems, or, indeed, in any part of the mechanism.

Arranged so as to show all aspects, the most careful measurements failed to show any wear in the valves and plugs. There was a carbonaceous deposit on the under aspect of the mushroom and the upper part of the stem, as indeed is usual with petrol, but there was very little on the top of the valve. The sparking plugs were also found in a clean condition, and were only removed once during the 3,000 miles run.

The carburettor was standard, and as normally fitted to the "Napier" cars. No alterations were made to it except that towards the end of the first week it was decided to enlarge the auxiliary air valve on the top of the carburettor, as it was found the engine would work with more air with this particular fuel. This valve was accordingly enlarged, and there was an immediate improvement in the mileage per gallon obtained, and the float was adjusted to suit the heavier spirit. The engine started from cold without any difficulty, and the driver of the car states that it was impossible to detect any difference between benzol and petrol in the driving, except that apparently the benzol would take more air. The specific gravity of the benzol varied from ·850 to ·885, but this apparently did not make any difference to the running.

On the worst day the car did 19½ miles to the gallon, and on the best day just over 25 miles per gallon. The average consumption throughout the 3,000 miles was 22·6. This result was obtained without "coasting."



NEW FORE END OF THE WHITE STAR LINER "SUEVIC."

The Reconstruction of the "Suevic."

By the courtesy of Messrs. Harland & Wolff we are able to illustrate the new fore-portion of the White Star liner *Suevic*, the wreck of which vessel will be still fresh in the minds of our readers. Following her running ashore it will be remembered that she was cut in half and the aft portion salved by fitting with a bulk-head, and afterwards towed successfully to Southampton. Meantime a new fore-portion has been constructed and towed to that port, and the process of jointing up the old and new portions of the vessel is now being proceeded with. This involves that the joint shall be equal in strength to the original ship, an undertaking which, in spite of its difficulty, may be with certainty left to Messrs. Harland & Wolff to accomplish. This will be secured not only by extra riveting, but by a new section of keel and extra long plates in decks and shell, all of which will overlap both old and new portions.

Live Steam Feed Heating.

Apropos of this subject, which was one of those set for a recent prize article competition, Mr. William Paterson, a well-known manufacturer of, and authority on, feed heaters and water purifiers, writes us as follows:—"Undoubtedly this is a fascinating subject. I have noticed there is quite a resurrection of appliances for live steam heating, but I am very doubtful as to the economy resulting from such apparatus in every-day working. Undoubtedly the heating and evaporisation of water are two distinct processes. The best type of plant for one process may not be suitable for the other. Therefore, if a boiler is called upon to simply evaporate water, not to heat it, there is no doubt increase in steaming efficiency. Internal live steam heaters are simply a resurrection of appliances adopted and abandoned years ago, as can be seen on referring to the Patent Office Records for the last fifteen to twenty years. As scale preventers they are of little use.

Take the case of a boiler evaporating, say, 500 gallons per hour. When steaming for 1,000 hours on water of 16 degrees hardness, half a ton of deposit will result, a duty these heaters are quite unable to fulfil. A live steam heater, to be of any use as a purifier, should be placed outside the boiler and of large capacity, with ready facilities for bye-passing the boiler feed when open for cleaning out. Engineers in this country do not fully recognise the economy obtainable by installing open type exhaust feed water heating and purifying plant. By this means a gain of 12 to 15 per cent. in steaming efficiency is obtained, and, further, about 20 per cent. of the condensed steam is recovered. There is a prejudice against open type heaters in Great Britain because of the difficulty in removing the oil. We can guarantee the absolute removal of all trace of oil by our system of coagulation and filtration. If engineers would fully appreciate the value of such appliances, very much greater benefit would result than can possibly accrue from the installation of any form of live steam heaters, either inside or outside the boiler."

The Franco-British Exhibition.

No movement in recent times has given more profound satisfaction to the people concerned than the growth of friendship with our French neighbours and the efforts made to extend our commercial relations with them. The commerce of France with the United Kingdom is of the most satisfactory description, and the idea of increasing the commercial intercourse between the two countries, and of materialising their friendly relations, by means of a joint exhibition was proposed by the French Chamber of Commerce in London towards the end of 1905, and was eagerly taken up on both sides of the Channel. An opportunity of inspecting the progress of the work of preparing the grounds and buildings was afforded to a representative Franco-British Press gathering at the end of November, and there is every indication that, vast as is the undertaking, everything should be in readiness in ample time for the opening date in May next. The site selected at Shepherd's Bush covers 140 acres. The principal entrance is immediately adjoining the station of the Central London Railway, and is close to Uxbridge Road Station, and in direct connection with the chief railways. It is, moreover, at the centre of a network of tramways and omnibus routes affording means of communication with all parts of London. The various methods of transport are capable of conveying 75,000 persons to the spot in the hour.

The exhibits will be housed in twenty buildings, eight of which will be each about 70 ft. wide by about 400 ft. long, and occupy a total area of about 4 acres. The French Committee has already secured one half of these buildings, which will be devoted to the Liberal Arts, Science, Social Economy, Hygiene, Chemical Industries, and Alimentation Sections. Among the larger buildings is the Machinery Hall, which will contain with its extensions over 250,000 sq. ft. of floor space, and will be the largest ever constructed in this country. Satisfactory evidence is existent to show that, large as it is, the capacity of this building will be strained to the utmost to accommodate all the exhibits. Among the applications for space we note the following:—Palmer's Shipbuilding Co., Lambton Collieries, A. Kenrick & Sons, Ltd., Geo. Hattersley & Sons, Ltd., Clayton, Sons & Co., Ltd., Central Marine Engine Co., Steel Company of Scotland, C. A. Parsons & Co., Holroyd & Co., Ltd., Watson, Laidlaw & Co., Ltd., Vickers, Son & Maxim, Mather Platt & Co., W. H. Allen & Co., Power Gas Co., Westinghouse Co., Ltd., D. Colville & Co., Hetherington & Co., North British Locomotive Co., S. E. & Chatham Railway, and other railways (English and French). Other palaces will be devoted to Education, Fine Arts, Decorative Art, Applied Arts, Music, and Woman's Work.

One-half of the entire space of the exhibition will be devoted to French exhibits, which will be more numerous than those displayed by France at any exhibition outside Paris. A special association has been formed to arrange for the representation of the French Colonies, and these have decided to send a collection illustrative of their produce and resources, that will occupy 275,000 sq. ft. The special committee for French agriculture has arranged to occupy about 40,000 sq. ft. of floor space, and it is expected that the British committee will take at least an equal area. The Municipality of Paris has voted £12,000 for the erection of a pavilion in which to display the archives and other records of the municipal work of the city.

The Government of India is spending £15,000 for the representation in a suitable building of the wealth of that portion of the British Empire. Canada has secured an area of 120,000 sq. ft., upon which will be erected a palace which will contain a collection of objects illustrating the produce and manufactures of the Dominion. Australia has taken 60,000 sq. ft.; New Zealand is well represented; Ceylon and the Crown Colonies will also participate upon an extensive scale, and in many cases special buildings will be erected by the respective Colonial Governments.

British manufacturers and producers now have an opportunity, such as they have not enjoyed since 1862, of showing in the capital of the Empire the progress which has been made in every department of invention and industry, and they will for the first time be able to exhibit with the aid of an organisation resembling that enjoyed for many years past by French exhibitors.

Machinery, Appliances and Processes.

The Editor invites advance particulars, drawings, blue prints, photographs, and any data that will enable him to publish an adequate description in these columns of any new work, machinery, or installation, possessing special features of interest. The cost of publication and engraving is borne by us, and no compensation is expected. In the endeavour to produce a really high-class and technically valuable machinery section the Editor seeks the co-operation of engineers and manufacturers.

Vertical Motor for High-Lift Centrifugal Pumps.

When a shaft-sinking pump is to be installed, high-lift centrifugal pumps are now very often chosen in preference to reciprocating pumps, over which they

FIG. 1.

have a number of advantages when applied to this class of work. Briefly stated, these are as follow:—A much higher lift can be dealt with by a single pump; the higher speed of the centrifugal pump renders it more suitable for direct coupling to an electric motor, enabling a smaller motor to be employed than would be necessary with a reciprocating pump; and lastly, a considerable saving of space results from the use of a centrifugal pump, especially as it may be constructed equally well with a vertical shaft as with a horizontal one. The electric motors for driving such pumps must, therefore, also be fitted with vertical shafts, and it is with these motors, rather than the pumps themselves, that this article deals.

A water-tight design must be adopted if the motor has at any time to work below the water level, but in the majority of cases this is not necessary, and sufficient protection is afforded by the provision of a drip-proof hood above the motor, which may therefore be of the fully-ventilated type, and consequently its size will be as small as possible in relation to its output.

The three-phase slip-ring type induction motor shown in Fig. 1, constructed by the Felten & Guilleaume-Lahmeyerwerke, A.-G., of Frankfort-on-Maine, for the Mont-Cenis colliery, has an output of 28 h.p., at 120 volts and 1,450 revs. per min. It is direct-coupled to a Weise & Monski one-stage centrifugal pump, which delivers 26,400 galls. of water per hour against a head of 147 ft. The top bearing of the motor is constructed as a suspension bearing and supports the rotor, while the lower bearing serves simply to guide the shaft. The pump has its own bearings, and is connected to the motor by a flexible coupling, which takes up any axial thrust.

In consequence of the absence of all sliding contacts in them, motors with short-circuited rotors are even more suited to this class of work than those of the slip-ring type. Fig. 2 shows such a motor, of

FIG. 2.

45 h.p. at 1,000 volts, 50 periods per sec., and 1,450 revs. per min., which was delivered to the Callar Stollen Mining Co., for direct coupling to a "Jaeger" sinking pump. The motor is started by means of an oil-immersed auto-transformer.

The motor shown in Fig. 3 is at work at the Zeche Ewald pit in Herten, Westphalia. It has an output of 185 h.p. at 500 volts, and 1,500 revs. per min., and drives a "Sulzer" high-lift centrifugal pump. The method of lubrication of this motor is worthy of note. A rotary pump in the circular chamber above the top bearing is driven by the motor shaft, and pumps oil from a vessel contained in the base of the motor through the tube shown on the right of the illustration to the top bearing. After passing through the bearing, the oil flows through a channel, arranged between the shaft and the rotor spider, to the lower bearing, and finally finds its way back to the reservoir. The overflow from the top bearing is also conducted to the reservoir through the pipe seen on the left of the motor. The capacity of the reservoir is about 4½ gallons, and thus the oil continually remains cool.

FIG. 3.

The motor is ventilated by means of a fan mounted on its shaft. Air is drawn in through the circular holes seen in the bottom of the motor base, and after passing through ducts provided in the stator and rotor, is expelled through the openings under the drip-proof hood.

Fig. 4 illustrates a ready mounted sinking pump at the Gabriela mine, Brandau, Bohemia. The water-tight motor is of the short-circuited rotor type, and develops 42 h.p. at 500 volts. and 2,900 revs. per min. The top of the motor casing is ribbed, to present a large radiating surface. At present the pump, which is by Messrs. Schwade & Co., of Erfurt, delivers 6,600 gallons of water per hour against a head of 525 ft., and requires 29 h.p. to drive it; a further stage will eventually be added, which will enable the pump to deal with the same quantity of water against a head of 690 ft., the power consumption then rising to about 38 h.p. The pump is fitted with a suction grid and foot-valve, a hand-operated regulating valve, and a non-return valve, and is, as may be seen from the illustration,

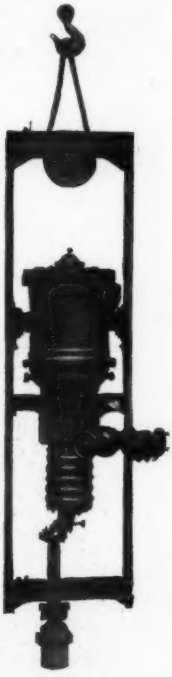


FIG. 4.

mounted together with the motor in a framework suspended from a steel rope. The connection between the pump and the motor is well cushioned with rubber rings, as it frequently happens that the pump has to work entirely under water. The motor terminal box is also made water-tight, and the leading-in cables thoroughly bushed with rubber.

The possibilities of application of the vertical motor are in no wise exhausted by the driving of sinking pumps. For instance, Fig. 5 shows a slip-ring type vertical induction motor, which develops 20 h.p. at 500 volts and 1,450 revs. per min., and is employed to drive the condenser circulating pump of a 600-kw. steam turbine at the Neuenkirchner Iron Works. In this case a drip-proof construction is naturally unnecessary.

Up to the present, alternating-current motors alone have been discussed, as, on account of their simple construction and the possibility of supplying them with current at a high pressure, they are particularly suitable for driving the class of machine considered. In some cases, however, and especially when the question of speed regulation arises, as with the driving

FIG. 5.

FIG. 6.

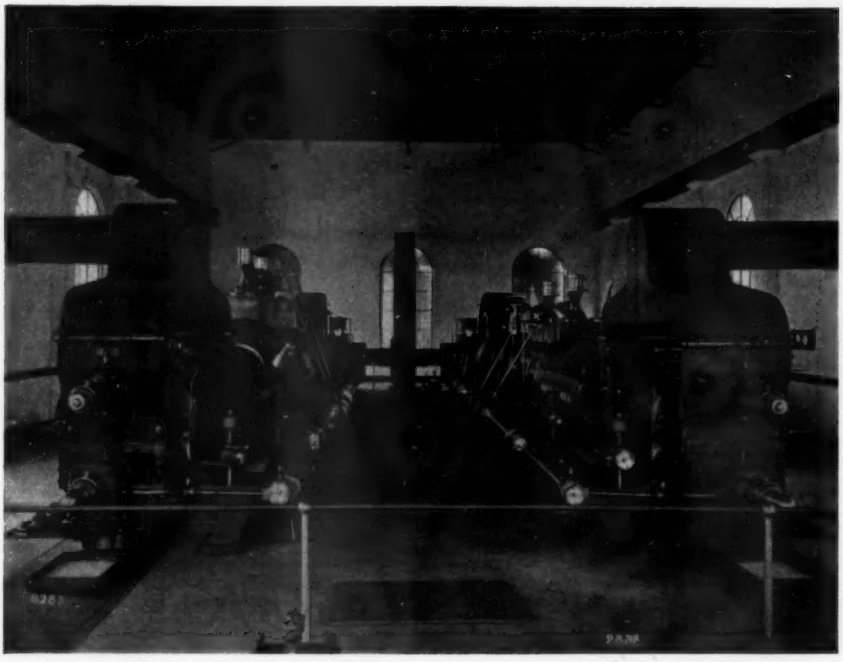
of hydro-extractors, &c., direct-current motors are to be preferred to them, and these may be equally well constructed with a vertical shaft. In Fig. 6 a vertical motor generator, also constructed by the Felten & Guilleaume-Lahmeyerwerke A.-G., is illustrated; it was so designed in order that the floor space occupied by the set should be as small as possible, and consists of a 6 h.p. direct-current shunt motor, and an alternator having an output of 3·6 kw. with a power factor of 0·6. The normal speed of the set is 1,500 revs. per min., but it may be regulated between 1,390 and 1,610.

1,200 Horse-Power Duplex Air Compressor.

The accompanying illustration is that of a 1,200 h.p. air compressor built for the Londonderry Collieries, Ltd., Sunderland, by Robey & Co., Ltd., Lincoln, under the "Daw" patents. The compressor supplies air for the underground haulage at the Seaham Colliery, and has two air cylinders, each 32 in. diameter by 72 in. stroke, driven by cross compound condensing steam engine having a high-pressure cylinder 30 in. diameter, and the low-pressure cylinder 52 in. diameter, each with 72 in. stroke. The compressor is arranged to run at 65 revs. per minute, or 780 ft. piston speed, and has a free air capacity of 8,600 cub. ft. per min. to 70 lbs. pressure.

A point of great commercial interest to users is the high piston speed and large output of the

compressor, and although the piston speed is stated to be higher than anything hitherto attained in this class of machinery, the compressor, we are informed, runs practically without any noise. The silent and efficient action of the compressor valves is due to the movement of the valves being controlled by an improved pneumatic control system. This control system is quite new in compressor construction, and by it the opening and closing of the inlet and delivery valves are controlled pneumatically, and gives to the valves full automatic action, with control of their opening and closing at their proper time, no matter how greatly the pressure in the receiver or the speed of the engine may fluctuate.



1,200 H.P. DUPLEX AIR COMPRESSOR.

The engine is arranged with the high and low-pressure cylinders on either side, and the air cylinders placed tandem behind them. The engine bedplates are of massive type, with the bored guides for the crossheads bolted direct to the cylinder flanges. The flywheel is 20 ft. in diameter and weighs 30 tons, the crankshaft and discs weigh 12 tons. The total weight of engine and compressor is 155 tons. The high pressure cylinder is fitted with double beat equilibrium steam and exhaust valves, and the well-known "Robey" trip valve gear. The governor is placed on the side of the cylinder working direct on the steam trip valve levers, giving automatic expansion for all loads, the fall of the valves being regulated by an improved dashpot to ensure silent running. The exhaust valves are actuated by an arrangement of levers to give rapid opening and closing.

The admission valve gear is of the positive gear type working on a rolling path and giving a rapid opening and closing. The whole of the valve gear is worked by two lay shafts running parallel to the engine beds and driven by worm gearing from the main engine shaft, the gearing being enclosed and running in an oil bath.

As the compressed air is principally used in underground haulage in the pit, there is at times considerable fluctuation in the demand, and to prevent waste of power an automatic governor is provided to regulate the speed of the compressor according to the quantity of air used. This automatic pressure regulator acts in conjunction with the engine governor and so regulates the speed of the compressor according

to the quantity of compressed air used by the pit, thus preventing waste of power.

Returning now to the air compressing cylinders, these, it will be seen on reference to the illustration, are double acting, and have one inlet and delivery valve arranged in each cylinder cover, and to control the silent opening and closing of these large valves and provide ample inlet and discharge area for the air at the high compressor piston speed of 780 ft. per min., rendered a special design necessary to meet these requirements.

The action of the air valve gear is as follows: The inlet valve is pivoted at the top and opens inward, and the opening and closing of the inlet valve is under the control of a small slide valve, which is actuated by an eccentric on the engine valve gear shaft. At the commencement of the suction stroke, the slide valve in its movement places the rear end of control cylinder in communication with the receiver pressure, so that the pressure in the latter acting on the piston overcomes the spring and weight of the valve. This pressure is maintained and the inlet valve is thereby kept in its open position from the time when it is opened and during the full length of the suction stroke.

The pressure set up on the inlet valve piston at the commencement of the suction stroke ensures the inlet valve opening instantly, and the inlet valve is of such large size and is given sufficient lift to prevent all obstruction to or wire-drawing of the air during admission, and the cylinder is filled with air at the full pressure of the atmosphere, thus doing away with one great cause of loss of efficiency.

On the completion of the suction stroke, the small slide valve is reversed to exhaust, and the spring being thus relieved of the pressure acting against it, closes the inlet valve. During the closing of the valve the control cylinder acts as a dashpot, the efflux of the compressed air being under control of a small regulating valve. The dashpot action by this arrangement is highly satisfactory, the valve at the highest speed of the compressor closing and opening, as before mentioned, at the exact moment without noise.

The delivery valve is pivoted in a similar way to the inlet valve and is arranged to open outward relatively to the compressing cylinder. The casing enclosing it is in open communication with the receiver, the pressure of which is always being exerted on the back of the valve.

In this compressor an improvement in the hinged flap form of valve consists in the formation of a series of openings through the delivery valve, acting in conjunction with corresponding bars formed in the valve seat opposite the openings in the valve, so that when the valve begins to lift, these transverse egress openings become available in addition to the ordinary peripheral opening round the valve, thereby nearly trebling the latter, or giving with moderate lift the maximum obtainable area of discharge.

The intervening bars increase the valve seating, and when the valve is closed, cause increased surface to be presented to the pressure in the receiver than to the pressure in the compressing cylinder over and beyond such increase as is caused by the peripheral seating, and to ensure sufficient working it is essential to balance all difference in pressure caused by the valve seating. This is effected by a balancing piston.

Much misapprehension prevails as to the necessity of balancing the valve seating, it being contended that air is enclosed between the valve face and its seating, and the pressure of such air tending to practically balance the difference in pressures caused by the seating. This, it is claimed, is erroneous, and should the air cards from valves not having the seating balanced show no rise in pressure, then such valves cannot be tight. The balancing piston is of such a diameter to balance the area of seating and overcome the weight of spring when the valve is closed. Now, with this large force pulling on the valve, it is stated that if there existed an appreciable pressure between the delivery valve face and its seating, the delivery valve would open much too early; the air cards, however, show the delivery valve to open exactly on the receiver pressure being reached. It is therefore evident that without the balancing piston a large increase in pressure in the cylinder over and above the receiver pressure would result before the delivery valve could open. Such excess pressure not only causes loss of work in compression but throws unnecessary stresses on the engine.

The control of the opening and closing of the delivery valve is effected through the small slide valve, placing the front end of balancing cylinder in communication with the receiver pressure, which, acting upon the piston, balances the difference in pressures on the delivery valve due to the valve seating, and causes the delivery valve to open, as shown by the cards, without any excess pressure being set up in the compressing cylinder. On the opening of the delivery valve the difference in areas of the valve surfaces exposed to receiver and cylinder pressures is instantly brought into equilibrium on the lift of the valve from its seat.

On the lifting of the delivery valve from its seat in addition to pressure on the balancing piston to pull and hold it open, considerable force is exerted by the pressure due to the velocity of efflux of the air from the compressing cylinder on the large valve surface, and to balance these forces and ensure the quiet opening of the valve the dashpot is provided. The volume of air used to control the balancing piston is simply what is required to fill the clearance space when the delivery valve is closed.

Throughout the design, attention has been given to every detail of construction for long, continuous running, the lubrication being practically automatic, and requiring a minimum of attention from the engineman.

Present requirements are met at Seaham Colliery by the compressor when running 48 to 50 revs. per min. and below we give particulars of a test run of the compressor at 62 revs. per min.

Dimensions of Compressor:	
Duplex air cylinders, diam. each ...	32 in.
Piston rods, diam. each	5 in.
H.P. steam cylinder, diam.	30 in.
Piston rod, diam.	6 in.
L.P. steam cylinder, diam.	52 in.
Piston rod, diam.	6 in.
Common stroke of all cylinders ...	72 in.
Revolutions per minute	62
Piston speed, feet per minute ...	744
Capacity, cubic feet of free air at 62 revs. per min.	8,209
Mean volumetric efficiency, shown by cards	96·2 per cent.
Net output of free air per minute at 62 revs., cubic feet	7,897
Temperatures:	
Temperature of atmosphere at air inlet	72° F.
Temperature of air at exit from compressing cylinder	320° F.
Temperature of cooling water at inlet to water jacket	119° F.

It will be observed that the cooling water temperature is somewhat high, and this accounts for the high temperature of the air at the outlet from the compressing cylinder. If the cooling water were of a lower temperature, a rather better efficiency in compressing would have been obtained. The volumetric efficiency of 96·2 for a single stage compression is at this very high piston speed very satisfactory.

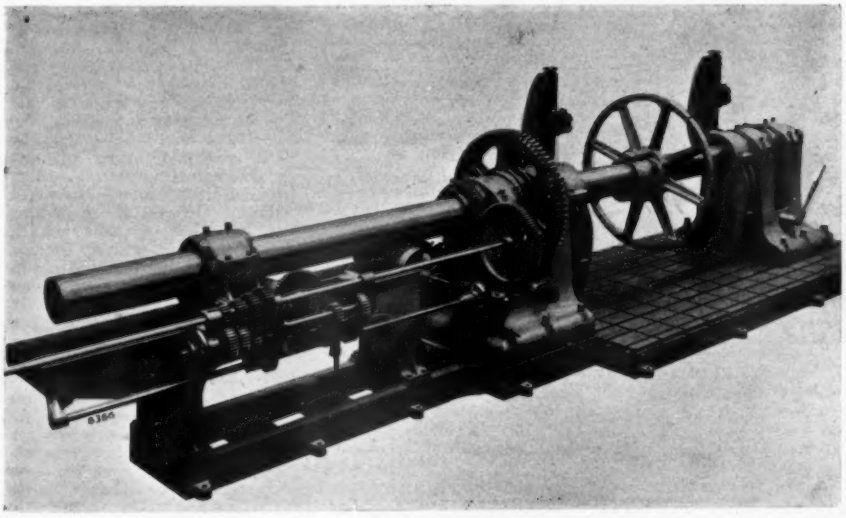
As already stated, the full speed of the compressor is 65 revs. per min. when its capacity is 8,600 cub. ft. per min. when 1,158 i.h.p in the air cylinders is obtained.

A test has shown that this requires 1,268 h.p. giving a mechanical efficiency of 91·32 per cent.

Cylinder Boring Machine.

By the courtesy of the makers, Messrs. Francis Berry & Sons, Sowerby Bridge, we are able to illustrate a powerful cylinder-boring machine for operating on cylinders up to 100 in. diameter and 120 in. long. It consists of a powerful driving standard with centres 5 ft. high, fitted with strong cast iron bushes to receive the wormwheel and facing arm. The loose rest is built on similar lines to the driving standard, and is fitted with bushes extended on each side, the rest being moved on the bed by means of a rack and pinion. It is fitted with planed tongues and grooves on the bed.

The main bed of cast iron is 10 ft. wide and bolted thereto is another baseplate, which carries, on two standards, a narrow table 3 ft. wide by 14 ft. long, to receive the fast head stock and back bearer for the boring bar. The over-all length of the machine is 45 ft. The forged steel boring bar is 16 in. diam., and 38 ft. long, having a keyway planed the full length. It is fitted with a shoe at the back end. The variable feed motion, either by hand or power, gives eight changes of feed from $\frac{1}{8}$ in. to $\frac{1}{16}$ in. The two double facing arms are keyed to the bushes. The boring head wheel is 8 ft. diam., and square steel cutters are secured in suitable slots



CYLINDER BORING MACHINE.

formed in its rim. All the gearing throughout is machine cut from the solid. The machine is driven by a 25 h.p. variable speed motor, and weighs about 60 tons.

Automatic Needle-Making Machine.

The accompanying illustrations, Figs. 1, 2, 3, and 4, show an interesting machine built by the Langelier Mfg. Co., Providence, R.I., for finishing sewing machine needles after they have been formed to shape on a rotary swaging machine of special design adapted to this particular class of product. According to *Machinery* the machine takes the swaged needle, which is fed into a magazine, cuts it to length, mills the grooves on the sides, perforates the eye for the thread, and rolls the number and name of the maker if required, upon the shank. The four functions of the machine are performed automatically, and because of this combination, if nothing more is conceded, it constitutes an interesting example of machine design which does what a number of machines are ordinarily required to do.

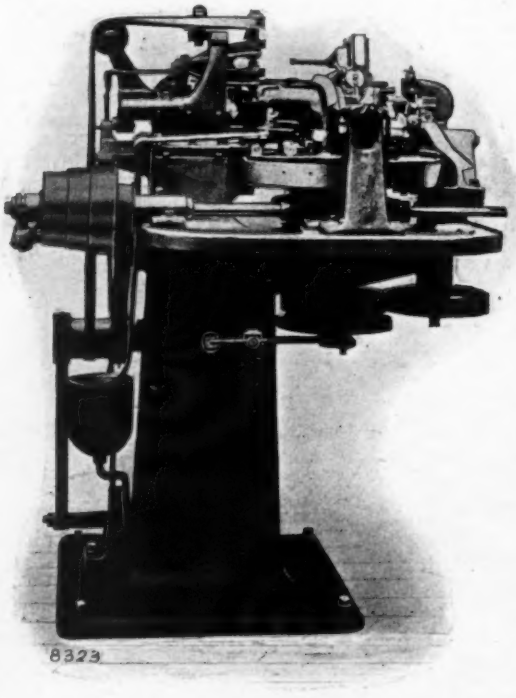


FIG. 1.—"LANGELIER" NEEDLE-MAKING MACHINE.

In this connection, it is interesting to note that needle manufacturing is one of the oldest arts, and that its machinery, though primitive, was ingenious and interesting, being among the earliest examples of special machinery used in the metal-working arts. Needles were made from steel wire, being cut from the coil without straightening, this having to be done individually for each pair of needles, it being the practice to make them two together, with the eyes in the centre. For many years the needle-makers of Redditch held a practical monopoly of the business of making hand sewing needles, but in after years German needle-makers sprung up who became active competitors, many workmen from England being imported to Germany to teach the art. The machinery of these older needle-makers, of course, was of a very primitive design, and it was all of the unit type, each machine being designed for one operation, and each required the superintendence of a workman for its operation, and the same condition largely exists still in European needle manufacture. In the United States the manufacture of needles and similar products is largely done by special machinery, and the machine illustrated may be regarded as a development of the American idea of making a machine that combines within itself a number of functions, which are automatically performed from start to finish without the interposition of manual labour.

Fig. 2 shows a plan of the machine, which is another adaptation of the turret principle in machine design. The needles are thrown into a magazine *F*, where they drop into the longitudinal slots of a revolving truncated cone-shaped receiver and undergo the first operation at *A*, which is cutting to length. Each needle in turn then drops from the receiver into the slot of a horizontal reciprocating trough that in itself contains the necessary mechanism for accurately loading each of the chucks as they arrive in position opposite the trough. At no time are the needles out of control of the mechanism. The turret then indexes the needle one-quarter turn and brings it opposite the grooving machine *B*, which consists of two vertical spindles carrying angular milling cutters. These work through narrow slots in a suitable grooved receiver, which holds the needle firmly in position while the cutters work on the opposite sides of the needle and produce the grooves required for the protection of the thread when penetrating the cloth. One side

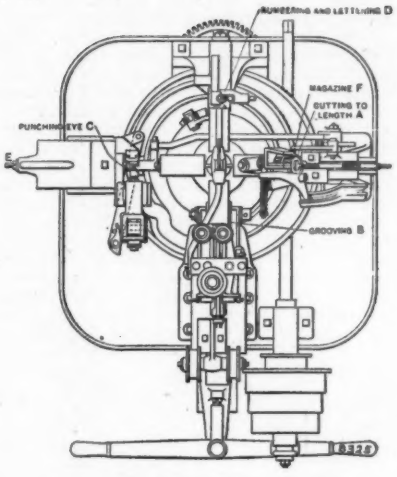


FIG. 2.—PLAN OF NEEDLE-MAKING MACHINE.

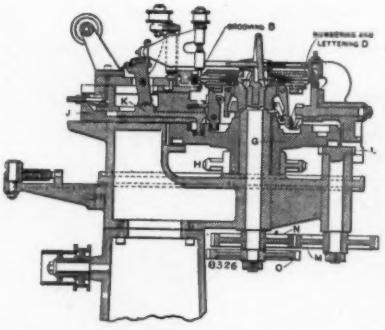


FIG. 3.—SECTION THROUGH NEEDLE-MAKING MACHINE.

of a needle has a longer groove than the other, and this difference in length is automatically effected by the mechanism. When the grooving has been completed, the turret again indexes to the third position *C*, where a punch automatically perforates the eye. The distance of the eye from the point is regulated by the screw *E*. The punches vary, of course, in thickness and width, according to the size of the needle and the size of the thread to be used. One size punch in common use, for example, is 0·032 × 0·014 inch. From this position, the turret again shifts the needle to the fourth position, *D*, where the number of the needle is automatically imprinted upon the shank, thus completing the functions of this machine. It

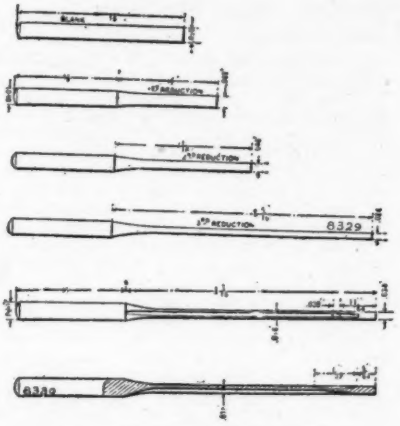
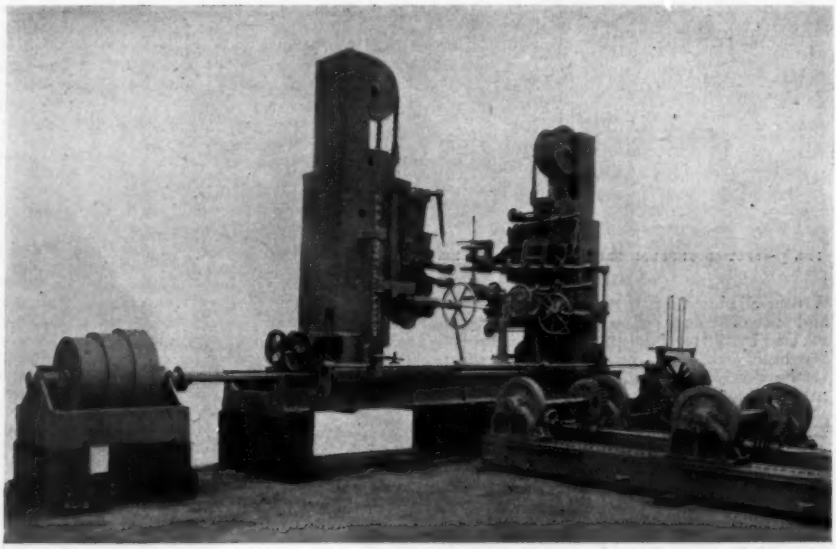


FIG. 4.—SUCCESSIVE STEPS IN SWAGING.

should not be concluded, however, that the needle after leaving the machine is practically completed. Far from it. It still has to be pointed, the eye has to be polished out so as to let the thread slip easily, and the whole needle has to be polished, besides going through a number of minor operations, but the four operations performed by this machine are, with the exception of the pointing, the principal ones that have to be done after it is swaged to form. An interested feature of design is the cam-plate *G*, Fig. 3, by which the functions of the turret operating tools are controlled. This cam carries two races on its upper side and one on the lower. The compound race on the upper side effects among others the pretty operation of controlling the feed-to-depth motion of the milling cutters and the longitudinal feed as well. This cam is in continuous motion, being driven by the worm-wheel *H*. The turret is actuated by a segment gear, attached to the under side of the cam-plate, which engages the pinion *L* and actuates the turret through gears *M* and *N*. Fig. 4 shows the successive steps of the operations of swaging, grooving and piercing of the needle. The automatic swaging machine takes the wire from the coil, straightens it, cuts off the blank from the wire by a milling operation and swages it to shape in three operations, the blanks being fed successively by a four-chuck turret having a horizontal axis, to the three heads of the machine. The design of the machine is positive. The principle of keeping the blank always within the control of the machine is carried out the same as in the grooving and eyeing machine, the blank being continually within the grasp of the chucks until the three swaging operations are completed. The swaging heads are made on the same principle as that employed in the regular "Langelier" machine.

Boiler Shell Drilling Machine.

In the manufacture of boilers, especially at the present day when it becomes necessary to increase the output and so reduce cost, by means of highly specialized tools, it is most satisfactory to note that one of the oldest manufacturers of machine tools in the North has come to the front with a machine embodying some very interesting features in its design. Messrs. G. & A. Harvey, Ltd., of Govan, who have now been in business for over fifty years are the makers of the boiler shell drilling machine here illustrated to whom we are indebted for the following particulars. The machine is fitted with four spindles of 3¼ in. diameter, with 18 in. feed, and is designed for using high-speed twist drills. It has been supplied to Messrs. D. Rowan & Co., of Glasgow, and has been satisfactorily tested up to expectation. In this machine the boiler is rotated for every second or third hole to be drilled; or, if desired, for every hole, instead of moving the saddles up and down. This is done by means of levers in front of the standards, and is a radical change from the usual practice, proving itself to be a good one, in as much as the operator has very much less exertion in the execution of his work. The operator has full control over the boiler, and can stop it almost exactly where necessary, leaving only a slight adjustment of the saddle and standard. This latter adjustment is accomplished by means of a hand wheel and double handle shown in front of the saddle. The hand wheel is for adjusting the standard to a small degree, but if a large adjustment is necessary the standard can be moved by power operated by the handle in front of it, and at a height just suitable for a man when standing. This handle is plainly shown on top of the round pillar. The power motion of the standard is obtained from a spur wheel keyed to the driving shaft in the bed operating a similar wheel keyed to the parallel shaft at the back of the standard. On this latter shaft is placed two mitre wheels, with a friction clutch between, gearing with a third in a position on the shaft at right angles, transmitting motion through a worm and worm wheel to a rack and pinion gearing into the rack in the bed. The spindles are driven from a three stepped cone, and thence through suitable gearing. The maximum speed of the spindle is 300 r. p. m., the minimum 250 r. p. m. Feeds are positive, being changed by a lever also in front of the saddles and operating a sliding spring key. The feeds are 68, 95 and 133 per inch. The saddles carrying the spindles are in four main pieces, and each spindle can be swivelled independently and set so as to point absolutely to the centre and remain so for the short travel on the standard given to them. They can be varied in pitch and brought close enough for drilling longitudinal seams. In this latter operation



BOILER SHELL DRILLING MACHINE.

the power traverse of the standard can be taken full advantage of, one being started at the end of the boiler, the other at the centre, both traversing the same way. One spindle only can be used when desired, the other being thrown out of operation. The spindles can also be adjusted independently for long or short drills, so that the points may enter the boiler at the same time. The upper spindle is carried in a separate adjustable slide and operated by means of ratchet, so that the holes are drilled in the exact position of marking off. As the saddle is moved up and down it is also swivelled by means of a worm working into a worm wheel segment at the top, and operated from a cross handle through change wheels at the back, different change wheels being used for boilers varying by 1 ft. in diameter. The boilers are carried on the usual castors, these latter being driven from large pulleys having open and cross belts. The beams on which the castors rest are provided with scales fixed on the sides for setting the castors for the various size of boilers, the range being from 8 ft. to 18 ft. diameter. Owing to the highest speeds used and the positive feed a powerful stream of cooling lubricant is required to be pumped on to the point of the drill.

The Engineer's Book-shelf

Books Received.

Modern Steam Traps: Their Construction and Working. By GORDON STEWART. (London: Technical Publishing Co., Ltd.) **3s. 6d.** net.

Notes on the Construction and Working of Pumps. By E. R. C. MARKS. (London: The Technical Publishing Co., Ltd.) **4s. 6d.** net.

The Balancing of Engines: Steam, Gas and Petrol. By ARCHIBALD SHARP, B.Sc., A.M.Inst.C.E. (London: Longmans, Green & Co.) Price **6s.** net.

Steel: Its Varieties, Properties, and Manufacture. By W. H. GREENWOOD. Revised and re-written by A. Humboldt Sexton, F.I.C., F.C.S. (London: Cassell & Co., Ltd.) Price **3s.**

Hydraulics. By S. DUNKERLEY, D.Sc., M.Inst.C.E. Vol. I. **Hydraulic Machinery.** (London: Longmans, Green & Co.) Price **10s. 6d.** net.

India-rubber and its Manufacture. By H. L. TERRY, F.I.C. (London: Constable.) **6s.**

Electric Power and Traction. By F. H. DAVIES, A.M.I.E.E. (London: Constable.) **6s.**

Liquid and Gaseous Fuels. By V. B. LEWES, F.I.C., F.C.S. (London: Constable.) **6s.**

Continuous-Current Engineering. By A. HAY. (London: Constable & Co.) **5s.** net.

Practical Coal Mining. Edited by W. S. BOULTON, B.Sc., F.G.S. Vol. II. and Vol. III. (London: Gresham Publishing Co.)

Practical Design of Irrigation Works. By W. G. BLIGH, M.Inst.C.E. (London: Constable.) **21s.**

Searchlights: Their Theory, Construction, and Application. E. NERZ. (London: Constable & Co.) **7s. 6d.**

Modern Machine Shop Practice. Vol. II. By RANKIN KENNEDY. (London: Caxton Publishing Co.)

Applied Mechanics. By JOHN PERRY, D.Sc., F.R.S. (London; Cassell & Co.) **7s. 6d.**

Electric Power Users' Handbook. By P. HUNTER BROWN. (London: Hodder & Stoughton.) **5s.**

Workshop Engineering Practice. By C. C. ALLEN. (London: Methuen & Co.) **3s. 6d.** net.

Corpuscular Theory of Matter. By J. J. THOMSON. (London: Constable & Co.) **7s. 6d.**

Town Gas and its Uses. By W. H. Y. WEBBER. (London: Constable & Co.) **6s.** net.

Coal. By JAMES TONGUE. (London: Constable & Co.) **6s.** net.

General Foundry Practice. By MCWILLIAM and LONGMUIR. (London: Griffin & Co.) **15s.** net.

Armature Construction. By HOBART and ELLIS. (London: Whittaker & Co.) **15s.**

Pocket Book of Electric Lighting and Heating. By S. F. Walker. (London: Crosby Lockwood & Co.) **7s. 6d.**

The Chemistry of Gas Manufacture. By H. M. ROYLE. (London: Crosby Lockwood & Sons.) **12s. 6d.** net.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

Civil Engineering.

Notes on the Erection of Bridges, VII. *Railway Engineer, November*, 1907.

Invar (Nickel-Steel) Tapes on the Measurement of Six Primary Base Lines. By C. B. French. *Proceedings American Society Civil Engineers, October*, 1907.

Bridle Roads in the West Indies. By H. C. Huggins. *Society of Engineers, 4th November*, 1907.

The Panama Canal, II. By W. Henry Hunter. *Times Engineering Supplement, 16th October*, 1907.

Discussion, Design and Specifications for a Reinforced Concrete Bridge Abutment. By T. M. Fyshe. *Transactions Canadian Society of Civil Engineers, October*, 1907.

The New Homberg Bridge. *Engineer, 1st November*, 1907.

The Quebec Bridge. By F. W. Skinner. *Engineering, 18th October*, 1907.

Modern Development of British Fishery Harbours, VII. By H. C. M. Austen. *Engineering, 25th October*, 1907.

Ferro-Concrete Viaduct for the Cala Mineral Railway, Seville. *Engineering, 18th October*, 1907.

The Protection of Rivers from Over-Pollution. By W. E. Adeney. *Times Engineering Supplement, 30th October*, 1907.

The Market Street Subway, Philadelphia. *Engineering Record, 12th October*, 1907.

Earth Slides. *Engineering Record, 5th October*, 1907.

The Extension, Widening and Strengthening of Folkestone Pier. By H. T. Ker. *Proceedings Institute Civil Engineers, 12th November*, 1907.

The Tranmere Bay Development Works. By S. H. Ellis. *Proceedings Institute Civil Engineers, November*, 1907.

The Quebec Bridge Wreck. *Engineering News, 10th October*, 1907.

Hydraulic Excavation and Dam Building at the Croton and Lyons Dams in Michigan. *Engineering News, 24th October*, 1907.

The Bracing of Trenches and Tunnels. *Engineering Record, 2nd November*, 1907.

Scours, Silts and Harbours. By R. G. Allanson-Winn. *Times Engineering Supplement, 6th November*, 1907.

The Detroit River Tunnel. *Engineering News, 31st October*, 1907.

Building.

The Reinforced Concrete Work of the McGraw Building. By Wm. H. Burr. *Proceedings American Society Civil Engineers, October*, 1907.

Sound Concrete Construction. By J. T. Noble Anderson. *Engineer, 11th* and *18th October*, 1907.

Reinforced Concrete in Holland. By S. J. Rutgers. *Concrete and Constructional Engineering, November*, 1907.

How to Prevent Failure in Concrete Construction. By Dr. W. Michaelis, Jnr. *Journal Western Society Engineers, August*, 1907.

Heating and Ventilation.

Ventilation of the Battery Tunnels of the New York Subway Extension to Brooklyn. *Engineering Record, 5th October*, 1907.

Materials and Measurements.

The Setting of Portland Cement, IX. By B. Blount. *Concrete and Constructional Engineering, November*, 1907.

Concrete as a Fire Resistant. By J. Sheppard. *Concrete and Constructional Engineering, November*, 1907.

Vanadium Steel. By E. F. Lake. *Machinery, October*, 1907.

Action of Sea Water on Concrete. *Railway and Engineering Review, 26th October*, 1907.

Boilers, Furnaces, and Fuel.

Blast-Furnace Gas as a sole source of Motive Power in Modern Ironworks. *Iron and Coal Trades Review, 1st November*, 1907.

Liquid Fuels for Internal Combustion Engines. By Robt. W. A. Brewer. *Proceedings Society Engineers, 7th October*, 1907.

Producer Gas. By J. Emerson Dowson. *Times Engineering Supplement, 16th October*, 1907.

Modern Power Gas Producer, Practice and Applications (*continued*). By Horace Allen. *Practical Engineer*, 11*th* and 25*th October*, and 8*th November*, 1907.

Steam Boilers (*continued*). *Practical Engineer*, 18*th October*, 1907.

The Rational Utilisation of Low Grade Fuels. By F. E. Junge. *Proceedings American Society Mechanical Engineers, October*, 1907.

Boiler Blow-off Connections. *Electrical World*, 2*nd November*, 1907.

Engines and Motors.

Thermal and Power Losses in Internal Combustion Engines, II. By A. H. Burnand. *Engineering*, 18*th October*, 1907.

Speed Regulation of Internal Combustion Engines. Its relation to Thermal Efficiency under varying Loads. *Engineer, Chicago*, 1*st October*, 1907.

Selecting an Injector. *Engineer, Chicago*, 1*st October*, 1907.

Contact Method of Gas Engine Ignition. *Electrical World, New York*, 19*th October*, 1907.

Steam Turbine Construction, I. By T. Franklin. *Mechanical World*, 1*st November*, 1907.

Engine and Boiler Trials, VII. *Mechanical World*, 11*th October*, 1907.

Long Range *v.* Short Range Trip Gears for Winding Engines. By R. H. Collingham. *Engineer*, 8*th November*, 1907.

Tests of Gasoline Engines using Alcohol. *Engineering Record*, 2*nd November*, 1907.

A 20,000 h.p. Rolling Mill Engine. *Iron and Coal Trades Review*, 18*th October*, 1907.

The "Sturtevant" Steam Turbine. *Engineering News*, 31*st October*, 1907.

The Prevention of the Short Stroking of Direct-Acting Duplex Pumping Engines. *Engineering News*, 31*st October*, 1907.

Hydraulics and Compressed Air.

Centrifugal Pumps. Two General Classifications, Volute and Turbine, and their Sub-divisions. By E. F. Doty. *Engineer, Chicago*, 15*th October*, 1907.

Centrifugal Pumps. Some Historical and Theoretical Considerations. By E. F. Doty. *Engineer, Chicago*, 1*st October*, 1907.

Notes on Centrifugal Pumps, I., II. *Mechanical World*, 25*th October* and 8*th November*, 1907.

Shop Equipment and Practice.

Reamers, III. By E. Oberg. *Machinery, October*, 1907.

Examining and Testing Files. *Machinery, October*, 1907.

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Faults of Iron Castings, I. By F. E. Cardullo. *Machinery, October*, 1907.

High-Speed Lathe Tools. *Mechanical World*, 18*th October*, 1907.

Notes on Mill Power Plant, XV. By C. J. Kavanagh. *Mechanical World*, 25*th October*, 1907.

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Modern Practice in Wire-Drawing Machines, II. *Engineering*, 1*st November*, 1907.

High-Speed Elevators. By Chas. R. Pratt. *Proceedings American Society Mechanical Engineers, October*, 1907.

Power Service in the Foundry. By A. D. Williams. *Proceedings American Society Mechanical Engineers, October*, 1907.

Formulas for Force required to Move Crane Trolleys. *Machinery, October*, 1907.

Notes on Rope Drives at Various Angles. By T. Hart. *Mechanical World*, 11*th October*, 1907.

Locomotive and Railway Engineering.

Recent Signalling in America (*concluded*). *Railway Engineer, November*, 1907.

The Locomotive from Cleaning to Driving, X. By Jno. Williams and Jas. T. Hodgson. *Railway Engineer, November*, 1907.

Combined Block Instrument, London and North-Western Railway. *Railway Engineer, November*, 1907.

The Development of the American Locomotive. Report of the Committee on Science and the Arts on the Contributions of the Baldwin Locomotive Works. *Journal Franklin Institute, October*, 1907.

Locomotive Coals. By A. Jacobsen. *Engineer*, 18*th October*, 1*st* and 8*th November*, 1907.

The Application of Highly Superheated Steam to Locomotives. By Robert Garbe. *Engineer*, 25*th October*, 1907.

Express Locomotive for the Prussian State Railways. *Engineering*, 11*th October*, 1907.

Shop Efficiency. By H. W. Jacobs. *American Engineer and Railroad Journal, October*, 1907.

A Method of Plotting Locomotive Characteristics. By L. H. Fry. *American Engineer and Railroad Journal, September*, 1907.

The Puy-de-Dome Mountain Railway. *Engineering News*, 10*th October*, 1907.

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Pusher Locomotive of the Mallet-Duplex Type for the Erie Railway. *Engineering News*, 3*rd October*, 1907.

Laycock's Low Pressure Steam Heating System for Railway Carriages. *Railway Gazette*, 18*th October*, 1907.

New Dynamometer Car for the Pennsylvania Railroad. *Engineering News*, 17*th October*, 1907.

Causes of Defects and Failures of Steel Tyres. By Geo. L. Norris. *Railway Gazette*, 8*th November*, 1907.

A Device for Straightening the Sills of Steel Cars. *American Engineer and Railroad Journal, November*, 1907.

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The 20 h.p. Valveless Car (*continued*). *Automotor Journal, 12th October*, 1907.

The Chenard-Walcker Carburetter. *Autocar, 12th October*, 1907.

Light Pistons. *The Autocar, 19th October*, 1907.

The Siddeley Shock Absorber. *Autocar, 19th October*, 1907.

Malleable Castings for Motor Cars, III. By P. J. Giron. *Mechanical World, 18th October*, 1907.

A Safety Gear Lever Lock. *Autocar, 26th October*, 1907.

The Effect of Speed on Fuel Consumption. *Autocar, 26th October*, 1907.

The Hydra High-Tension Magnets. *Automotor Journal, 26th October*, 1907.

Road Dust and Automobile Engines. By G. D. Macdougal. *Autocar, 2nd November*, 1907.

The Lynton Resilient Wheel. *Automotor Journal, 9th November*, 1907.

The Rollason Six-Stroke Petrol Engine. *Autocar, 9th November*, 1907.

Electric Lighting.

Electric Street Lighting Twenty Years ago. By A. Scheible. *Western Electrician, 28th September*, 1907.

Electrical Generation and Transmission.

The Secondary Current of the Induction Coil. By H. Clyde Snook. *Journal Franklin Institute. October*, 1907.

Units used in Distribution. By W. A. Toppin. *Electrical Engineer, 1st November*, 1907.

The "Thury" Direct-Current Transmission System. By D. Kos. *Electrical World, New York, 26th October*, 1907.

Electric Power Supply in Yorkshire. *Electrical Engineering, 31st October*, 1907.

Some Recollections of Central Station Development. By Samuel Insull. *Western Electrician, 28th Sep.ember*, 1907.

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The Deri Single-Phase Commutator Motor. *Electrical Engineering, 24th October*, 1907.

Three Low-Head Hydro-Electric Developments in Michigan, I., II. *Engineering Record*, 19th and *26th October*, 1907.

The Transmission Plant of the Niagara, Lockport and Ontario Power Company. By R. D. Mershon. *Proceedings American Institute Electrical Engineers, September*, 1907.

Line Constants and Abnormal Voltages and Currents in High-Potential Transmissions. By Ernst J. Berg. *Proceedings American Institute Electrical Engineers, September*, 1907.

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A 2,000-volt Continuous Current Railway. *Railway Gazette, 25th October, 1st* and *8th November*, 1907.

The Yew York, New Haven and Hartford Railway (*continued*). *Electrician, 11th October*, 1907.

Electric Traction on Railways (*continued*). By P. Dawson. *Electrician, 1st November*, 1907.

Steel Tie and Concrete Construction on the Utica and Mohawk Valley Railway System, Utica, New York. By M. J. French. *Street Railway Journal, 12th October*, 1907.

Maximum Length of Service for Poles, Ties and Timbers. By Ed. H. Weihe. *Street Railway Journal, 12th October*, 1907.

Papers and Reports Presented at the Atlantic City Convention of the American Street and Inter-urban Railway Engineering Association, and Proceedings, October 14th, 15th and 16th, 1907. *Street Railway Journal, 19th October*, 1907.

The Hardness of Corrugated Rails. By Geo. L. Fowler. *Street Railway Journal, 5th October*, 1907.

Track Construction and Corrugation, Philadelphia and Boston Experiences. *Tramway and Railway World, 3rd October*, 1907.

The Rise of the Electric Railway. By B. J. Arnold. *Western Electrician, 28th September*, 1907.

Single-Phase Equipment of the Rochester Division of the Erie Railroad. *Electrical World, New York, 12th October*, 1907.

Recent Improvements in Catenary Line Construction and Methods of Installation. *Street Railway Journal, 26th October*, 1907.

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A 2,000-volt Continuous-Current Railway. *Electrical Engineering, 24th October*, 1907.

Heavy Electric Traction on the New York, New Haven and Hartford Railroad. *American Engineer and Railroad Journal, November*, 1907.

Of Friction. By W. M. M. *Tramway and Railway World, 7th November*, 1907.

The "Robrow" Conduit System as adopted for Benares Tramways. *Tramway and Railway World, 7th November*, 1907.

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Tests of Large Turbo-Generators in the United States, I. *Engineer, 1st November*, 1907.

A Method of Testing D.C. Networks for Insulation Resistance during Working. *Electrical Review, 11th October*, 1907.

The Losses in Heavy Alternating Current Cables. *Electrical Review, 11th October*, 1907.

Systematisation in Electrica' Power Station Design. By A. G. Ellis. *Electrical Times, 10th October*, 1907.

The Permeability of Alloyed Irons at High-Flux Densities. By E. A. Watson. *Electrician, 18th October*, 1907.

Electrical Pumping at Lindal Moor Mines. *Electrical Review*, 18*th October*, 1897.

The Dielectric Strength of Insulating Materials and the Grading of Cables. By Alex. Russell. *Transactions Institute Electrical Engineers*, *November*, 1907.

Switchboard Wire Protection. By T. W. Poppe. *Electrical World*, *New York*, 5*th October*, 1907.

Wiring and Connections for Constant Potential Transformers. By Geo. A. Burnham. *Electrical World*, *New York*, 5*th October*, 1907.

Measurement of Electrolytic Resistance. *Physical Review*, *October*, 1907.

A Method of Laying Vitrified Conduits for Electrical Cables, and a Collapsible Core for forming Conduits in Concrete without the use of Vitrified Ducts. By F. Lavis. *Engineering News*, 3*rd October*, 1907.

The Grounded Neutral, with and without Series Resistance in High Tension Systems. By P. M. Lincoln; Experience with a Grounded Neutral on the High Tension System of the Interborough Rapid Transit Co. By Geo. J. Rhodes; The Grounded Neutral. By F. G. Clark. *Proceedings American Institute Electrical Engineers*, *September*, 1907.

Wireless Telephony. *Electrical Engineering*, 7*th November*, 1907.

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The Sensitiveness of Photometers. By L. W. Wild. *Electrician*, 8*th November*, 1907.

Wiring with Iron Conduit. *Electrical World*, *New York*, 2*nd November*, 1907.

Marine Engineering and Naval Architecture.

The Screw Propeller, XV. By A. E. Seaton. *Marine Engineering and Naval Architecture*, 1*st November*, 1907.

The Accident at the Launch of the *Principessa Jolanda*. *Engineering*, 11*th October*, 1907.

The New Cable Steamer *Guardian*. *Electrician*, 18*th October*, 1907.

Notes on Boat and Anchor Cranes. *International Marine Engineering*, *November*, 1907.

The Vessel of the Future. By A. R. Liddell. *International Marine Engineering*, *November*, 1907.

Motor Boat Propellers. By Geo. R. McDermott. *International Marine Engineering*, *November*, 1907.

New Swiss Lake Steamers. *International Marine Engineering*, *November*, 1907.

Water Supply.

Sand Filtration of Water Supplies, I. By A. Williamson. *Engineering*, 1*st November*, 1907.

Streets and Pavements.

Sewage.

The Treatment of Sewage. By Prof. F. Clowes. *Times Engineering Supplement*, 16*th October*, 1907.

The Sewage Purification Plant at Reading, Pa. *Engineering Record*, 5*th October*, 1907.

Engineering Economics and Works Management.

The Organisation of a Jig and Tool Department. By J. Younger, B.Sc. *Engineering*, 25*th October*, 1907.

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Foundry Blower Practice. By W. B. Shaw. *Proceedings American Society Mechanical Engineers*, *October*, 1907.

The Use of Winding Ropes, Safety Catches and Appliances in Mine Shafts. *Colliery Guardian*, 11*th October*, 1907.

Diffusion Phenomena in Flames. By R. Casaubon. *Journal of Gas Lighting*, *&c.*, 15*th October*, 1907.

The International Congress for Hygene and Demography. *Engineering News*, 24*th October*, 1907.

Some Foundry Experiences. Being some Considerations on Starting an Engineering Foundry. By A. R. Bellamy. *Transactions Manchester Association Engineers*, 9*th November*, 1907.

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Floods and Means of their Prevention. By T. P. Roberts. *Proceedings Engineers' Society Western Pennsylvania*, *October*, 1907.

Vanadium Steel. By J. Kent Smith. *Proceedings Engineers' Society Western Pennsylvania*, *October*, 1907.

Manchester Gas Exhibition. *Journal of Gas Lighting*, *&c.*, 29*th October*, 1907.

The Arrangement of Cage Guides for Modern Collieries, II. *Iron and Coal Trades Review*, 25*th October*, 1907.

The "Crystallisation" of Metal. By W. Rosenhain. *Times Engineering Supplement*, 6*th November*, 1907.

The Electrolysis of Salt Solutions in Liquified Sulphur Dioxide at Low Temperatures. By Dr. B. D. Steel; The Action of Aluminium Powder on Silica and Boric Anhydride. By F. E. Weston and H. Russell Ellis. *Proceedings Faraday Society*, 29*th October*, 1907.

TRADE LITERATURE.

Drysdale & Co., Glasgow. Spanish edition, well illustrated and printed, of this firm's catalogue. This is a commendable enterprise on the part of Messrs. Drysdale, whose example we should like to see followed more generally by manufacturers who have been all-too-slow in heeding the warnings of Consular Reports as to the futility of issuing trade literature in other than the language and measurements of the country to which it is addressed. **Edward G. Herbert, Ltd.,** Manchester. Catalogue of file testing machines, bell hinges, centring tools, drill starters, &c. **Siemens Bros. & Co., Ltd.,** London, S.W. Catalogue No. 502 of thermo-electric pyrometers, temperature indicators and recorders. **British Fuel Economiser and Smoke Preventer,** 9, Bedford Row. Booklet descriptive of the "Bunsen" bridge apparatus for smoke prevention and economising fuel. **Robert A. King & Co.,** 66, Victoria Street, S.W., have forwarded us one of their general catalogues, and from this we note that in addition to their ordinary business of new and second-hand machinery merchants, the firm holds several good agencies for electrical and other supplies which should interest our readers. They now represent the following firms:—Millen & Sommerville, Glasgow, constructional engineers, manufacturers of steel roofing, girder work, forgings, &c. The Comet Oil Flare Lamps for Contractors made by the above firm. Smithson, Sharpe & Co., Manchester, makers of arc lamps, carbons, and resistances. Laurie & Co., West End, Falkirk, makers of "Laurie & Inglefields" system of travelling electric lights and stretching pendants. Messrs. King & Co. also send lists illustrating Motors, Dynamos, Steam Sets, &c., which are made for them by a well-known north of England firm. **Clarke, Chapman & Co., Ltd.,** Gateshead-on-Tyne. Complete general catalogue of ships' auxiliary machinery, both steam and electric, mining plant, water tube boilers and pumps. **B. J. Hall & Co., Ltd.,** 39, Victoria Street, S.W. Sectional catalogue No. 1 of drawing instruments and No. 8 of the "Ordoverax" process for the photo-copying of drawings. **Reavell & Co., Ltd.,** Ipswich. Pamphlet No. C 11, dealing with air-compressors. We understand that the developments with this type of compressor for electrical work have been considerable, and a large portion of the firm's output is now composed of electrically-driven compressors, with motors of both continuous and alternating currents. They are largely used for coal and metalliferous mining, as well as for pneumatic work in workshops of various kinds. In many other industries also where electricity is being adopted as a motive power our compressors and vacuum pumps are being increasingly used.

WORKSHOP PRACTICE PRIZE COMPETITION.

The result of the Third Prize Competition is announced on page 409.

Our Fourth Prize Competition will also relate to Workshop Practice, and will be limited to Works Managers, Foremen, and those under their charge, to provide an opportunity of bringing their practical ideas and experiences into print.

Four prizes are offered—one of £4 and three of £1—for the best short article describing and illustrating any emergency device or any job which has taxed the ingenuity of the machinist, pattern maker, fitter or foundry operator.

The award will be announced in the February number.

Instructions and Conditions.

Articles must be written on one side of the paper only, and be signed by the competitor.

Drawings and sketches must be on separate sheets of paper.

A short biographical sketch of the competitor's technical experience should accompany the article.

The right is reserved of publishing the prize article, and also any of the others sent in; but in the case of the latter, payment will be made for the same at our usual scale rates.

The Editor's decision in all matters connected with the competitions shall be final, and binding on all the competitors.

All articles should be addressed to the Editor of The Engineering Review, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and the same must be received not later than January 15th.